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PSYCHOMETRIC AND ORAL FUNCTION ASSESSMENT OF PATIENTS TREATED BY THE USE OF IMPLANT-RETAINED PROSTHESES

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LIST OF ABBREVIATIONS

0-C	Obsessive-Compulsive
16-PF	Sixteen Personality Factors
ADA	American Dental Association
ANX	Anxiety
CD	Complete Denture
CDMIE	Council on Dental Materials, Instruments and Equipment
cm	Centimetre
CMD	CranioMandibular Disorder
CMI	Cornell Medical Index
DC	Direct Current
DEP	Depression
EMG	Electromyography
EPQ-R	Eysenck Personality Questionnaire
GHQ	General Health Questionnaire
GSI	Global Severity Index
HC	Hollow-Cylinder
HLC	Health Locus of Control
HOS	Hostility
HS	Hollow-screw
I-S	Interpersonal sensitivity
IMZ	Intra Mobile Zylinder
ITI	International Team for Implantology
kg	Kilogram (1Kg=9.8 Newton)
mm	Millimetre
MMPI	Minnesota Multiphasic Personality Inventory
MOF	Maximum Occlusal Force
MSBP	Mandibular Staple Bone Plate
N	Newton
OCD	Optimised Conventional Denture
OPT	Orthopantomogram
OVD	Overdenture
PAR	Paranoia
PC	Personal Computer
PCD	Previous Complete Denture
PHOB	Phobia
PSDI	Positive Symptom Distress Index
PST	Positive Symptom Total
PSY	Psychoticism
r	Correlation Coefficient
SCL-90-R	Symptom Check-List
SD	Standard Deviation
SOM	Somatization
SPSS	Statistical Package of Social science
SS	Solid-Screw
TMI	Trans-Mandibular Implant
VAS	Visual Analogue Scale

DECLARATION

This thesis is the original work of the author.

SALAH AL-OMOUSH

DEDICATION

To my Mother;

I wish you long life, with my love and respect

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SUMMARY

The loss of natural teeth followed by alveolar bone resorption results in the deterioration of the alveolar ridges. These atrophic changes, particularly in the mandible, contribute significantly to a reduction in the stability, retention and load bearing capacity of complete dentures. In addition to a compromised functional capacity, there is a loss of facial support and a reduction in face height. In recent years the use of osseointegrated dental implants for the rehabilitation of edentulous and partially dentate subjects has gained considerable clinical acceptance owing to the high clinical success rates reported. In addition to improvements in dental function there are reported psychological benefits for patients treated with implants, particularly in the case of patients who previously have suffered long-standing problems with conventional complete dentures.

It is useful for the dentist to have an insight into the psychological make-up of patients, particularly when considering the edentulous patient's expectations of what will be achieved from the provision of dentures. Clinical success requires not only the use of appropriate techniques and materials, but depends also upon patients' adaptation potential and upon influences such as motivation and behavioural patterns. The most common complaints arising following the provision of conventional complete dentures are lack of denture stability/retention, pain/discomfort, reduction of masticatory function, difficulty with speech and aesthetic problems, all of which may cause varying degrees of psychological dissatisfaction.

In this study, there are two sections. Chapters One and Two comprise the first section. In Chapter One there is a description for the history of implant dentistry and a brief review of the main dental implant systems currently in use. Chapter Two consists of a prospective psychometric analysis of two groups of edentulous patients to investigate their psychological profiles before and after implant treatment. The first group consisted of twenty edentulous subjects who were followed-up over a three year period, using the Cattell's 16-PF psychological test. A second group of ten edentulous subjects were assessed over a shorter period of time using the SCL-90-R psychological test.

The second section of this work consists of three chapters developing the work started in Chapter Two dealing with the group of ten edentulous subjects, who had been selected from the waiting list at Glasgow Dental Hospital. All had been referred to the Department of Prosthodontics with long-standing problems centred on their mandibular complete dentures; problems such as denture instability and discomfort, often associated with psycho-social difficulties.

The main aims of the present study were:

(1) To provide all ten patients with new complete dentures of optimised design and to evaluate the outcome of this treatment by measuring of patients' speech and bite force. Patient self-evaluation of masticatory function, denture stability, comfort, appearance, self-confidence, social interaction, patients' perception of their prostheses, and overall satisfaction was also measured, by the use of self-administered questionnaires designed specifically for this purpose. In addition, the psychological status of patients was evaluated with the use of professionally analysed psychological tests. These assessments were carried out three months after the patients started wearing optimised conventional dentures.

(2) To provide all ten patients with mandibular implant-retained overdentures anchored by two implant fixtures with ball attachments, to evaluate this treatment outcome and to compare it to the earlier conventional denture treatment. Two months after the use of the implant-retained overdentures all the above assessments were repeated, in order to allow comparison with respect to the evaluated variables.

(3) To assess any correlation between maximum occlusal force as measured by the use of a bite force transducer, speech performance as measured by means of perceptual analysis and the subjective measure of patients' perception of treatment outcome as assessed by self-administered questionnaires, before and after implant treatment.

With the optimised conventional dentures, from self-assessment questionnaires it was found that in the patients' opinion there was a moderate improvement in most aspects of denture function, although some patients reported continuing difficulties with chewing food.

Following implant treatment it was apparent from the second self-assessment questionnaire, where the comparison was made between the optimised conventional dentures and the implant-retained overdentures, that the patients considered that there was a significant improvement with respect to the evaluated variables. There was strong support for the view that the implant-retained overdentures functioned considerably better than did the conventional dentures of optimised design, and that this was owing to the increase in denture stability provided by the implant fixtures.

There was a significant increase in the maximum occlusal force values reported after provision of the implant-retained overdentures and furthermore there was a strong correlation between subjectively self-assessed masticatory function and objectively-measured bite force. In addition there was a finding that those patients with largest denture-bearing areas generated the greatest occlusal bite forces before and after implant treatment.

Little or no change in speech quality was found after upper-denture modification, or after patients had been provided with implant-retained overdentures. It was concluded in this part of the study that speech quality, which was not the most significant problem for this group of patients, was not an aspect of denture function which could be assessed objectively to allow before and after treatment comparison.

There was little measurable change in psychological profiles before and after implant treatment. It seems that even with the use of appropriate methods of psychometric assessment other life events, or problems that patients might have had, exerted a greater influence on psychometric profile over time than dental treatment or denture stability. On the other hand, patients reported a considerable improvement in psycho-social activity when assessed by means of subjective dental function questionnaires.

In conclusion, the use of implant-retained overdentures proved to be a successful option for treatment of patients with chronic complete denture problems. The use of two implant fixtures to retain a mandibular denture appeared to provide an improvement in

denture stability and comfort, masticatory function and self-confidence when patients were evaluated by self-assessment questionnaire. Of the objective methods of assessment investigated, only bite force measurement seemed to offer the opportunity for development, although further investigation in this field is required.

The clinical investigations described in this work were carried out in accordance with the ethical standards required by the Greater Glasgow Health Board Area Dental Ethics Committee.

CHAPTER ONE

REVIEW OF CURRENT PRACTICE IN IMPLANT DENTISTRY

1.1 INTRODUCTION

Archaeological records have traced the beginning of rudimentary dental implantology to ancient Egyptian and South American cultures (Lee, 1970; Lemons & Natiella, 1986). More recent attempts to replace missing natural teeth by means of metal implants have been documented over several decades (Greenfield, 1913; Strock, 1939; Linkow, 1968; Bodine et al, 1976). However, it is only over the period of the last twenty years that oral implants have become accepted in mainstream dentistry as a predictably successful option for the rehabilitation of partially dentate and edentulous patients.

According to Scharer and Chen (1993), in the nineteenth century dentists used many different types of alloplastic materials such as gold, porcelain and Indian rubber in an attempt to replace lost teeth. Greenfield (1913) introduced an endosteal implant, which consisted of a two-piece hollow basket implant made of irridio-platinum. By 1939, Strock had inserted the first cobalt-chromium-molybdenum alloy screw-shaped implants, both in surgically prepared sites and in extraction sockets. At this stage Strock noted the need for primary stability. Following the work of Stock a number of endosseous implant designs were developed. Formiggini (1947) introduced the spiral design which was followed by a double- helical implant described by Chercheve (1962). Subperiosteal implants began clinical use towards the end of the 1940s. The original idea for a customised metal framework to be placed directly onto edentulous saddle areas was introduced by Dahl (1943) and modified by Goldberg & Greshkoff (1949).

Linkow (1964) introduced the vent-implant made from a chromium-nickel alloy. Other implant designs have included ramus frame implants, which consist of a one piece implant in the shape of a tripod supported by the symphsis anteriorly and the ascending ramus posteriorly (Roberts & Roberts, 1970; Roberts, 1987), mandibular staple implants (Small, 1975), and the transmandibular implant (Bosker, 1986).

Most progress during the period from 1913 to 1970 was made throughout the world of private practice with little interest or support from the academic institutions for dental

implant research and little published long-term follow-up of clinical cases. Commercial interest often obscured scientific fact and many implant developments were derived from an individual dentist's concept. However, over the last twenty years there has been considerable development in clinical and laboratory-based research in this field.

In 1952 at the University of Gothenburg Professor Branemark and his team, investigating blood rheology and wound healing using titanium observation chambers, more or less by chance discovered the biocompatability of titanium in the course of animals experiments. The potential of titanium as an implant material was subsequently developed through further laboratory experimentation and clinical trials (Branemark, 1965). In 1969, Branemark et al described direct bone contact with a metallic implant, and in 1977 Branemark et al, called this phenomenon osseointegration.

Despite progress in the field of oral implantology, data on long-term clinical follow-up and success rates are available for only relatively few implant systems such as Branemark (Adell et al, 1981,1990; Albrektsson et al, 1988), ITI (Schroeder et al, 1988; Buser et al, 1997), IMZ (Babbush & Shimuura, 1993) and Astra (Arvidson et al, 1992). However, because of methodological differences and varying definitions of clinical success it is often difficult to make reliable comparisons between the clinical data reported by various authors.

According to Spiekermann et al in 1995 there were more than 100 different implant systems commercially available world-wide. In the USA, more than 40 dental implant systems are available for clinical use. The Council on Dental Materials, Instruments and Equipment (CDMIE) and the American Dental Association (ADA) have established an acceptance programme for dental implant systems, and in order to be adjudged acceptable or provisionally acceptable, an implant system must be tested and approved by experienced practitioners, as well as by the CDMIE and ADA. To achieve this acceptance, manufacturers must provide evidence of biocompatability and materials testing, as well as clinical follow-up statistics from at least two independent studies with 50 patients (Standford, 1991; Donovan and Chee, 1992).

1.2 Fibro-integration and Osseointegration

Natural teeth are supported by the highly specialised tissues of the periodontal ligament (Lindhe & Karring, 1989) and in the past researchers in the field of dental implants have sought an alternative for the periodontal ligament.

Early studies emphasised the importance of having differentiated fibrous tissue around metallic implants as being essential for implant survival and function. However, in many cases, such implants tended to become mobile with time owing to widening of the fibrous tissue layer with subsequent implant failure (Southam & Selwyn, 1970; Osborn & Newesly, 1980). While some authors have reported that fibrous tissue formation around a dental implant is desirable for its survival (Linkow, 1970; Weiss, 1986,1988), evidence from the clinical studies supporting the desirability of a connective tissue capsule adjacent to the implant is not convincing. Results of studies conducted by Cranin et al (1977), Armitage (1980) and Smithloff & Fritz (1982,1987) showed clinical survival rates which varied from 49% to 55% for 5 to 10 year follow-up.

An alternative attachment mechanism was described by Branemark et al (1969). In contrast to fibro-integration, the direct structural and functional connection between living bone and the surface of a load carrying implant seems to establish a bond which become stronger with increasing time (Branemark, 1985), and survival rates of up to 86% in the mandible and up to 78% in the maxilla over a 15 year follow-up period have been reported (Adell et al, 1990). Based on the observations of Branemark, in order to achieve successful osseointegration, the following prerequisites apply. Surgery at the implant site should be atraumatic, there must be primary stability of implant fixtures and there must be a period for undisturbed healing before implant fixtures are loaded. The use of appropriate implant materials is also of primary importance.

On the basis of the long-term clinical results obtained with a number of osseointegrated implant systems it seems justified to conclude that tooth loss can be safely treated using osseointegrated techniques with minimal risks of unwanted tissue reactions, provided proper protocols for the handling of the host tissues and load distribution are followed (Branemark et al, 1977; Eriksson & Adell, 1986; Sutter et al 1988; Buser et al, 1988).

1.3 Implant materials

There have been reports on the use of a large number of different materials in the quest to find a suitable substitute for the natural tooth. At various times metals such as gold, stainless steel, silver, platinum, irridium, vitallium (cobalt-chromium alloy), titanium, and non-metallic materials in form of porcelain, polymers, ceramics and carbon have been used. Greenfield (1913) used platinum, Venable et al (1936) found that cobalt-chromium alloy produced no electrolytic action when buried in tissue and in 1939 Strock reported on the use of cobalt-chromium alloy in the shape of a root-form implant. Secord & Breck (1940) reported on the inability to remove cobalt-chromium alloy screws from a bone plate. Good results have recently been reported with the use of niobium (Albrektsson et al, 1993). At present, commercially pure titanium appears to be the metal of choice for dental implants. Titanium has proven compatibility with the living tissue and it has good mechanical properties. It is many times stronger than cortical bone and histological studies have demonstrated intimate contact between titanium and the peri-implant bone (Albrektsson et al, 1981; Hansson et al, 1983; Steinemann, 1996). The chemical properties of the implant surface are determined by the surface oxide of the titanium which has different chemical, physical and mechanical properties from the pure metal itself (Kasemo, 1983; Albrektsson et al, 1983).

Although it has been shown that the titanium oxide surface undergoes minimal change in the biological environment over periods of time extending up to several years, in some studies titanium ions have been found in the adjacent bone (Dorre, 1980), in the peri-implant mucosa (Weber et al, 1986) and in the regional lymph nodes as well as other organs such as liver, spleen and kidney (Williams, 1981).

Sundgren et al (1986) reported an increase in thickness of the oxide layer of titanium implants in humans from 5 to 200 nanometers over a 10 year period of follow-up. *In-vitro* studies have also shown an increase in oxide layer thickness with time (Healy & Ducheyne, 1992). It is difficult to estimate the release of titanium ions from implants accurately because titanium ions also enter the body in many chemical forms each day via various food stuffs. The average titanium intake in humans per day is 0.3-1 mg and the daily excretion rate is 0.3 mg through urine (Wenning & Kirsh, 1988; Steinemann, 1996). It is thought that factors such as manufacturing and sterilisation procedures, surface morphology, functional stress and local pathological processes may influence

ion transfer from implants to host tissue (Parr et al, 1985; Doundoulakis, 1987). Kasemo & Lausma (1985) reported an increase of oxide layer thickness in the elevated temperature and humid atmosphere found during sterilisation procedures. The biologic half-life of titanium (320 days) is too short for it to accumulate in the body (Kasemo & Lausma, 1985; Steinemann, 1996) and to date the literature contains no reports of any disease or allergic reaction directly attributable to the placement of titanium implants.

The modification of implants has been introduced to produce a roughened surface by the use of plasma spray, sandblasting, acid-etching, and laser treatments. These techniques are standard practice in the production of fixtures in a number of implant systems. Scanning electron microscopy studies have shown that bone is able to grow into intimate contact with roughened titanium surfaces without an intermediate connective tissue membrane (Schroeder et al, 1976; Schroeder et al, 1978; Kirsch & Mentag, 1986; Steinemann, 1996). It has been suggested that a porous roughened surface provides an increase in the strength of the implant-to-bone bond when compared to a smooth surface interface, and that there is an increase in osteoinduction activity which in turn may improve the long-term stability of the bond between implant and bone (Schroeder, 1991).

Hydroxyapatite surface coatings have been used in some systems since the mid 1980s, with a view to accelerating osseous healing and improving osseointegration. Studies have shown that implants with a hydroxyapatite coating can have clinical success rates of 95% over a five years period (Krauser, 1989; Kent et al, 1990; Kirsch & Ackermann, 1991). However, a number of failures with hydroxyapatite-coated implant have also been reported (Weinlaender, 1991; Johnson, 1992). Some hydroxyapatite-coated implants have shown cracks or even complete loss of the hydroxyapatite-coating, with heavy colonisation with micro-organisms also occurring, particularly in those parts of the HA-coating exposed in the oral cavity following gingival recession (Krauser et al, 1991; Ramus & Roberts, 1991).

1.4 Parameters for implant success

Albrektsson & Zarb (1993) defined osseointegration as a process where clinically asymptomatic rigid fixation of alloplastic materials in bone is achieved and maintained during functional loading. The key factors for achieving osseointegration have been proposed and reviewed by Albrektsson et al (1981) and Albrektsson & Zarb (1993) who highlighted the importance of material biocompatability, implant design, implant surface, state of the host tissue, loading conditions and surgical technique.

Many criteria have been proposed in the dental implant literature to help define success in implant treatment. Schnitman & Shulman (1979) emphasised the importance of the following factors as indicators of the success of implant treatment; the fixture mobility should be less than 1 mm in any direction, radiologically observed radiolucency graded but no success criterion defined, bone loss of no greater than one third of the vertical height of the implant fixture, any gingival inflammation amenable to treatment, absence of symptoms, infection and parasthesia or anaesthesia and no violation of the mandibular canal, maxillary sinus and nasal cavity. Finally, to consider implant treatment successful, implants should provide functional service for five years in 75% of treated cases.

Cranin et al (1982) proposed the following factors as indicators of implant success; an implant should be in place for 60 months or more, there should be a lack of significant evidence of cervical saucerization on radiographs, freedom from haemorrhage as measured using Muhlemman's index, a lack of mobility, absence of pain, no peri-cervical granulomatosis or gingival hyperplasia and no evidence of widening of peri-implant space on radiographs. McKinney et al (1984) proposed, subjective criteria (which include adequate function, absence of discomfort, patient belief that aesthetics are satisfactory and improved emotional and psychological attitude) and objective criteria (consisting of bone loss no greater than one third of the height of the implant, any gingival inflammation susceptible to treatment, mobility of less than 1 mm in any direction, absence of symptoms and infection, absence of damage to adjacent tooth or teeth, absence of paraesthesia or violation of mandibular canal, maxillary sinus and the floor of nasal cavity, and functional service for 5 years in 75% of treated patients).

Relatively strict criteria were suggested by Albrektsson et al (1986) who proposed that the unattached individual implants should be immobile when tested clinically, radiographs should show no evidence of peri-implant radiolucency, the vertical bone loss should be less than 0.2 mm annually following the first year of function, each individual implant should be characterised by an absence of persistent signs and symptoms (such as pain, infection, parasthesia or violation of the mandibular canal or the maxillary sinus) and, in the context of the above, a success rate of 85% at the end of 5-year follow-up period and 80% at the end of a 10-year period should be the minimum criterion for success. Smith & Zarb (1989) proposed criteria for implant success which were similar to those of (Albrektsson et al, 1986), with the addition that the implant design sould not preclude placement of a crown or prosthesis with an appearance that is satisfactory to the patient and dentist.

The two main methods of measurement of the state of osseointegration of oral implants are controlled testing of implant stability at different intervals during follow-up and the use of standardised radiographs (Albrektsson & Zarb, 1993) with the absence of mobility regarded as the most important of clinical signs (Branemark et al, 1977; Adell et al, 1981; Albrektson et al, 1986; Smith & Zarb, 1989; Buser et al, 1990a; Albrektsson & Zarb, 1993).

An additional clinical method of assessment has become available with the use of the *Periotest*®apparatus (Periotest, Siemens AG, Bensheim, Germany). The *Periotest*® was developed by Schulte & Lukas (1992) to measure the damping characteristics of the periodontium of natural teeth and has subsequently been used for implants. The *Periotest*® was designed to diagnose periodontal disease by measuring damping characteristics by percussion, thus giving a change in sound within the device from a high to a low pitch. It indirectly measures tooth or implant mobility and, it is claimed, provides information about bone resorption. The device is similar in size and shape to a dental handpiece, with an electronically controlled head to percuss a tooth or implant fixture at a rate of four times per second. The tapping head is decelerated once it hits the tooth or implant abutment. The healthier the periodontium, or the more ankylotic the implant, then the hydrodynamic damping effect is effectively higher and the faster the deceleration. According to Olive & Aparicio (1990) the *Periotest*® allows objective

clinical measurement of implant stability which may help detect non-osseointegration of implants before final prosthetic restoration is commenced.

There is general agreement that the standard periodontal-indices are poor indicators of treatment success with osseointegrated dental implants (Apse et al, 1991; Zarb & Albrektsson, 1991; Albrektsson, 1993). Smith & Zarb (1989) pointed out that there is little evidence that the sulcus depth is related to implant health, although it is recognised that gingival inflammation is not a desirable response. Lekholm and Zarb (1985) demonstrated that the presence of deep pocketing is not necessarily correlated to an accelerated marginal bone loss.

Implant survival is often misquoted to indicate implant success, and Albrektsson & Sennerby (1991) have suggested that when success rates are presented defined criteria should be identified. Albrektsson (1993) suggested a method of reporting the outcome of treatment in a four grade scale; success, survival, failure and unaccounted for. Within the 'success' category are included those implants that have been tested for and meet all of the success criteria, including stability testing and radiographs. In the 'survival' category are those implants still in the jaw of the patient that have not been checked for mobility and radiographic examination has not been undertaken. Implants in the 'unaccounted for' category include all those in patients who died or dropped out of the study, or who were not available at the recall appointment. Normally, the larger the number of 'unaccounted for' implants, the more uncertain will be the estimates of implants success or survival. It has been suggested that any research reports that do not describe the precise number of 'unaccounted for' implants should be regarded as unacceptable for publication (Albrektsson, 1993). The 'failure' category includes all removed implants, irrespective of the cause of failure or removal, and implants in which the degree of mobility is an absolute sign of failure, irrespective of whether or not the implant is still in the patients' jaw.

1.5 Classification of Oral Implants

There are a number of different types of dental implant design currently available for use in dental practice and the most widely used classifications of these makes reference to the form and position of the implant substructure.

The least invasive type of implant is the ***sub-mucosal*** implant which is almost universally condemned. It consists of a button-like retention device inserted into a superficial incision in the mucous membrane of the residual ridge, with the purpose of providing retention and stability for a prosthesis. Dahl (1943) introduced the first sub-mucosal implants. Owing to poor retention, short survival rates, trapped food debris, and regular occurrence of acute bacterial infection, the use of this type of implant has been largely discontinued (Van Steenberghe, 1993).

Sub-periosteal implants consist of a metallic frame placed directly on the superior surface of the jaw and kept in place by the overlying periosteum. The designs vary from narrow metal strips held by screws Goldberg & Gershkoff (1949) to bilateral cast metal frameworks reinforced to improve rigidity and to provide equal distribution of forces throughout the frame (Bodine & Vakay 1978). They are mostly used in the mandible but can be used in the maxilla. Sub-periosteal implants are placed using a 2-stage surgical protocol. A crestal inscion is made, under a strict sterile clinical conditions and an impression taken of the jaws (Berman, 1952). A customised metal frame is constructed from the resultant cast and installed as part of a second surgical stage.

Bodine (1974) reported a success clinical rate of 100% at 3 years, 66% at 10 years and 22% at 20 years and concluded that the use of the subperiosteal implant should be restricted to the mandibular arch and used only when opposed by a mucosa-supported complete denture. However most studies reporting a success rate with sub-periosteal implants have used relatively vague criteria for assessment and the results have been largely subjective (Bodine & Vakay, 1978; Goldberg, 1978).

Along with relatively high failure rates, it is recognised that the possible spread of infection along the path of the metal framework beneath the mucoperiosteum can lead to widespread bone resorption (Bodine et al, 1976; Goldberg and Gershkoff, 1970). Consequently they have become less frequently used at the present time, perhaps being

considered only when there is insufficient bone to accommodate an endosseus implant fixture, for selected patients (Van Steenberghe, 1993).

Transosseous implants are implantable devices which are inserted through the full thickness of the mandible by the use of an extra oral approach. They are used relatively infrequently in the UK, and the main indication is in the restoration of the severely atrophic mandible. A number of different designs have evolved with the best known being the Mandibular Staple Bone Plate (MSBP) and the Transmandibular Implant (TMI).

The ***Mandibular Staple Bone Plate (MSBP)*** was introduced by Small (1975) and comprises two transosteal posts made of titanium alloy (consisting of 90% titanium, 6% aluminium and 4% vanadium) which penetrate the full thickness of the mandible between the mental foramena, with 3 to 5 small cortical pins which are secured in the cortical bone of the inferior border of the mandible. The implant is usually inserted under general anaesthesia using an extra oral approach through an incision in the submental fold. The transosteal pins are linked using a mandibular plate at the inferior border of the mandible. Six to eight weeks after surgery a tissue-borne prosthesis is constructed using resilient Dalbo or Ceka attachments.

Small presented the results of the survey of 43 staple implants that had been functioning for 5 years at the Harvard Consensus Conference on dental implants of 1978. A number of other long-term studies have been published and in general, success rates in excess of 90% have been reported (Small, 1979; Helfrick et al, 1982; Kent et al, 1984; Small & Misiek, 1986; Wittenberg & Small, 1995).

The ***Trans-Mandibular Implant (TMI)*** system is also an extra-oral transosseous implant, developed in the Netherlands and introduced by Bosker (1986). It is used in the rehabilitation of the severely atrophic mandible without the need for bone grafting procedures (Bosker et al, 1991a). The implant system consists of a rigid box-frame structure which, it is claimed, controls and evenly distributes the masticatory forces along the atrophic mandible, provided the overdenture prosthesis is implant-borne. The box-frame structure consists of a superstructure (Dolder Bar), baseplate, four transosseous posts and five cortical screws. Unlike most other osseointegrated implants

systems, the TMI is made of 18 karat gold alloy (70% gold, 5% platinum, 13% silver and 12 % copper) which is corrosion-resistant and bio-inert (Bosker, 1986). The TMI system is placed under general anaesthesia using an extra-oral approach procedure in the submental area. The prosthetic procedure is undertaken after a period of three months, the patients being provided with an overdenture (Jordan & Bosker, 1991; Powers & Bosker, 1996).

An overall long-term success rate in excess of 98% has been reported with the use of TMI system (Bosker & Dijk, 1989; Maxson et al, 1989; Bosker et al, 1991a) and it has been claimed from retrospective evaluation that bone induction occurs giving an increase in bone height posterior to the transosseous posts, in the severely atrophic mandible (Bosker et al, 1991b).

According to Van Steenberghe (1993) the main drawbacks associated with the TMI system, which equally apply to the MSBP transosseus implant system, are that the procedure involves major surgery which exposes the patient to the hazard of general anaesthesia and an extra-oral scar, and in the event of implant failure the removal of implant hardware is difficult and may result in significant bone loss. The technique is also limited in as much as its use is restricted to the edentulous lower jaw.

Root-form endosseus implants

A major change in restorative dentistry has come about in the last two decades owing to the development of root-form osseointegrated endosseus implants, from the original work of Professor P-I Branemark **(Section 1.1).** Alongside the academic progress following research by Branemark at the University of Gothenburg (1965), there has been the commercial development of the Nobel Biocare (Nobelpharma) implant system, also commonly known as the ***Branemark system.*** This implant system, based on decades of research and development is considered the bench mark in implant dentistry by many, and there have been a number of other commercially developed implant systems which have design features which closely resemble the design and the protocols used in the Branemark system. Branemark implant fixtures are available in solid screw-shape with a number of different diameters ranging from 3.75 and 5.0 mm. The fixtures are made of commercially pure titanium and each diameter of fixture is made in

different lengths. Each implant unit consists of a number of interlinking components; the fixture, abutment, abutment screw, gold cylinder and gold screw (Branemark et al 1969). The coronal part of the fixture has a hexagonal shaped projection with an internal threaded channel. Following the installation of the fixture and the completion of the healing period the chosen abutment is screwed into place on the main fixture by means of a titanium screw which itself is used to secure the superstructure (Hobo et al, 1990).

It is normal practice for these procedures to be carried out using two surgical stages, the first for fixture placement, followed by placement of a healing abutment which precedes the connection of the appropriate abutment to link with the superstructure. A detailed surgical protocol has been described, particular importance being given to atraumatic preparation of the fixture bed, good primary stability of the implant fixture and favourable loading of the fixtures in the immediate post-operative period (Branemark et al, 1969; Eriksson & Albrektsson, 1984; Branemark, 1985). A minimum period of three to six months is recommended to ensure tissue healing before the implant fixtures are loaded. After completion of the healing period, the second surgical stage is carried out and construction of the final prosthesis is undertaken. The prosthesis may be a removable implant-retained overdenture anchored by stud, magnet or bar attachments or it may be a fixed crown or bridge prosthesis.

Implant systems based on the Branemark system

Several implant systems have been introduced with characteristics similar to the original Branemark design. In some cases no long-term clinical follow-up studies have been associated with these systems, although, according to Albrektsson (1993), every individual implant system should be backed-up by controlled reporting of the clinical outcomes over a five year period in four field table, within the categories of success, survival, unaccounted for and failure

The ***Steri-Oss*** implant system (Denar Corporation, Anaheim, Canada) which utilises a two-stage surgical technique and is also based on the principles advocated by Branemark. The fixtures are available in screw-form, made of commercially pure titanium as well as hydroxyapatite-coated cylinders. In a three-year follow-up study in partially dentate and edentulous subjects patients a success rate of 93.6% in the

mandible, 98.3% in the maxilla was reported (Hahn, 1990; Hahn & Vassos, 1993). Saadoun & LeGall (1992) reported a success rate of 90.2% in the maxilla and 94.5% in the mandible following-up 673 Steri-Oss implants over a five year period.

The ***Astra*** implant system (Astra Meditec, Molndal, Sweden) follows a number of the protocols laid down by Professor Branemark in his original concept for the Branemark implant system. A two-stage surgical approach is used and the fixtures are made of commercially pure titanium in screw form, with a variety of lengths and diameters. The self-tapping fixtures are connected with a one piece conical-shaped abutment for restoration (Arvidson et al, 1990). A number of prospective short and long- term follow-up studies have been carried out to evaluate the success rates and bone reactions associated with Astra dental implants. Arvidson et al (1992) evaluated the clinical performance of 310 implants over a three year period, reporting a success rate of 98.1%. Murphy et al (1992) found a success rate of 95% for 128 implants without specifying the length of the follow-up period. In a study by Walmsley et al (1993) a success rate of 90% was reported for a series of 70 implants with magnetic retainer to stabilise overdentures, with a follow up period of approximately three years.

As described above, with respect to Sterio-Oss implants, a number of implant systems have followed a protocol similar to that described by Branemark, but have used titanium implant fixtures which have a hydroxyapatite coating. In animal studies hydroxyapatite-coated implants have been shown to have a significantly higher mechanical bond with bone than uncoated implants (Block et al, 1987; Mefferet et al, 1987). A commonly used hydroxyapatite-coated system is the ***Integral*** implant system (Calcitek Inc, Carlsbad, California). However, it has been reported that the implant surface is unstable owing to the high rate of bio-degradation of the hydroxyapatite layer and it has also been reported that hydroxyapatite-coated implants show cracks in, or even a complete loss of, the hydroxyapatite coating (Krauser et al, 1989). Block & Kent (1991) reported 16 implant fractures within a group of 243 hydroxyapatite-coated implants used for overdenture stabilisation. In a prospective study of 6,200 Integral implants Stultz et al (1993) reported, in a multicentre study with 5 year follow-up period, a cumulative survival rate of 95.7% in the mandible and 93.2% for Integral implants placed in the maxilla. Kent et al (1990) reported a 95% success rate in a five year clinical study of

772 hydroxyapatite-coated Integral implants in 229 patients and an overall success rate of 94% of Integral implants after three years was reported by Yukna (1992).

Block and Kent (1991) placed 62 Integral implants in extraction sockets immediately after tooth removal in 34 patients. The success rate for these Integral implants was reported as 97% for four year follow-up period, which was at a similar level to the results found from placement of hydroxyapatite coated implants into healed bone. Similar findings were reported by Yukna (1992). These results suggest that the Integral implant can be placed successfully in fresh extraction sockets using otherwise standardised implant placement techniques and principals.

Besides the Branemark and the Astra implant systems, which originate from Sweden, other implant systems which are commonly used in Europe are the IMZ, the Tubingen and the ITI systems. These originated independently from the work of Branemark as their original design features would suggest.

The ***IMZ*** implant (Interpore, Irvine, California) was developed in Germany in the early 1970's by Dr Axel Kirch. IMZ implants are available with two different surface coatings; a titanium plasma sprayed implant and hydroxyapatite-coated implant. The IMZ implant is cylindrical in form and perforations permit the ingrowth of bone in the apical region. The main feature which distinguishes the IMZ system from the other implant systems is the presence of a so-called 'intra-mobile element' between the implant body and the superstructure, initially developed to assume the role of the periodontal ligament in providing a shock absorption mechanism to reduce the magnitude of impact forces transmitted to the bone interface (Babbush et al, 1990). A two stage surgical protocol is used in placement of IMZ fixtures, and clinical indications include single tooth replacement, free-end saddles restoration and reconstruction in edentulous jaws (Babbus, 1991).

Kirsch & Mentag (1986) reported a success rate of 95% on 1814 implants from two clinical centres with a 7.5 to 8.5 year follow-up period. Babbush et al (1990) reported on the two year follow-up of 5230 titanium plasma-sprayed and hydroxyapatite-coated

implants, indicating that there was a two year survival rate of 97.3%. Survival rates in excess of 92% were reported by Babbush & Shimura (1993) a over five year period.

In a retrospective study a total of 2623 IMZ implants were assessed after a five year period in partially and completely edentulous patients by Fugazzotto et al (1993). Cumulative success rates of 92.9% were recorded in the maxilla and of 95.8% were recorded in the mandible. Lill et al (1993) conducted a retrospective comparison study to evaluate the success rates of 683 IMZ and Branemark implants over a three year follow-up. A success rate of 87% was recorded for the Branemark implants and of 91% was recorded for the IMZ implants.

The ***Tubingen*** Implant System (Frialit, Friedrichsfeld, GmbH, Mannhcim, West Germany) was originally designed and developed by Professor Schulte in collaboration with Dr Heimke at the University of Tubingen, West Germany for use in immediate single tooth replacement. In the original design (Frialit-1) the implant fixtures were manufactured from polycrystalline aluminium oxide ceramic. This has been replaced by the Frialit-2 fixture, made from commercially pure titanium and used in a two-stage surgical procedure. The fixture remains covered during the healing phase. The implant body is a stepped cylinder to imitate the conical shape of a tooth root. The Frialit-2 system is available in a press-fit stepped cylinder or self tapping step screw with varying lengths and diameters, with plasma sprayed or hydroxyapatite-coatings (D'Hoedt, 1991).

The Tubingen implant (Frialit-1 and Frialit-2) may be used for immediate or late replacement of teeth (Quayle et al, 1989 a). In immediate replacement it is essential that tooth removal is carried out with minimal trauma to the ginigiva and alveolar bone and it is recommended that loosening of the attached gingiva and the periodontal ligament is achieved by the use of periotomes and that extraction is carried out using fine forceps to allow minimal trauma. The length of the socket is measured as is the tooth width at the cervical margin. The appropriate length and diameter of implant is selected and a stepped cone drill is used to create the definitive implant bed. While few clinical studies

have reported on success rates, Schulte (1984) reported a success rate of 90% over five year follow-up period and Quayle et al (1989 b) reported a success rate of 88% for two year period, for delayed placement.

All of the implant systems described to this point were designed to be used with a two-stage surgical protocol. The only major implant system which currently is used with a one-stage surgical procedure is the ***ITI®*** implant system. The development of the ITI implant system involved collaboration between the Department of Operative Dentistry at the University of Berne, Switzerland and the Straumann Institute (Schroeder et al, 1976). ITI implants are transmucosal or transgingival from the onset, using a one step surgical protocol (Sutter et al, 1988; Ten Bruggenkate et al, 1991). This system has been used on a regular basis within Glasgow Dental Hospital since 1988.

ITI implants are available as one-part or two-part designs and come in a number of sizes and forms. The use of the one-part design is rarely reported. There are three forms of the standard two-part implants; the hollow cylinder, hollow screw and solid screw designs. The hollow cylinder is available as a straight fixture or as a fixture with a 15^{o} angulation at the cervical end. The cylinders are 3.5 mm in diameter and the standard screw-form design has a diameter of 4.1 mm. The solid screw designs are also available in diameters of 3.3 mm and 4.8 mm. The intra-bone length of the fixtures varies from 6 mm to 16 mm.

Each implant fixture has a smooth polished collar, 2.8 mm in height, which flares out from the variable fixture diameter to give a standard diameter for abutments of 4.8 mm. The design concept for the use of the perforated hollow cylinder and hollow screw implants was to provide effective implant anchorage with bone growing through these perforations, giving a strong integrated union between the internal bone segment and the bone surrounding the implant, minimal bone removal during implant bed preparation and reduced levels of stress between bone and implant due to the ingrowth bone through the implant perforations (Sutter et al, 1988). Unlike most other endosseous implant systems, ITI implants are transmucosal from the time of fixture placement and at fixture

installation the 2.8 mm polished titanium cuff is left above the bone level and the mucoperiosteal flap is closely adapted around the implant neck (Sutter et al, 1988)

For endosseous implants to achieve osseointegration with high predictability, it has been determined that the implants must be inserted with atraumatic surgical technique, they must be placed with initial stability and they should not be loaded during the healing period of three to six months (Eriksson & Albrektsson, 1984; Branemark 1985; Sutter et al, 1988; Buser et al, 1990a & b). When these clinical guidelines are followed, it has been reported that successful osseointegration will occur predictably for non-submerged implants (Gotfredsen et al, 1990; Weber et al, 1992).

Consequently, perceived advantages of the ITI system are that it requires only a single stage surgical intervention, the components for the ITI system are relatively simpler than are required for two-stage procedures and with hollow fixtures less bone removal is necessary during preparation of the implant bed (Sutter et al, 1988). It also suggested that hollow cylinder implants are well suited to those situations requiring minimal fixture length (Buser et al, 1991).

The ITI implant body has a roughened surface coated with a titanium plasma-sprayed layer of 30 micrometer thickness. This technology has been used by a number of other implant systems (IMZ and Steri-Oss) and it is claimed that this rough surface characteristic results in more rapid bone deposition and increases bone-to-implant contact by up to six times in comparison with a smooth surface. The epithelial tissue around the smooth surface of implant neck appears to attach in a manner similar to that found on a natural tooth (Buser et al, 1991).

1.6 Objectives of the Research Project

From this review of the literature it is clear that the use of dental implant is a well established and predictably successful method of treatment, effect in dealing with partial and total loss of teeth. However, clearer methods of identifying priorities in treatment need and in defining measures of treatment outcome, particularly for the edentulous individual, would be beneficial.

In the following chapters, details of experimental work undertaken into several aspects of clinical patient assessment by functional and psychometric methods, before and after implant treatment, are comprehensively described.

CHAPTER TWO

SATISFACTION AND ACCEPTANCE OF COMPLETE DENTURES AND IMPLANT PROSTHESES

2.1 REVIEW OF LITERATURE

Although loss of teeth is a common disability which, in the majority of cases, does not lead to an extreme psychological reaction, clinical experience shows that a number of edentulous patients have major concerns about their oral state. There is little doubt that the wearing of complete dentures can lead to a severe loss of confidence, and the inability of the individual to accomplish oral functions such as the chewing of certain types of food or the articulation of clear speech may lead to the avoidance of some social activities (Demers et al, 1986; Kent & Blinkhorn, 1991). In severe cases there may be adverse psychological reactions towards edentulism, varying from anxiety, fear and rejection to deep and prolonged depression (Friedman et al, 1987).

Friedman et al (1988 a & b), studying the factors that have an effect on patients' responses to tooth loss and wearing dentures, highlighted important factors which included parental influences, the symbolic significance of teeth and current life circumstances. Haugejorden et al (1993) showed that losing one or more teeth and starting to wear a denture can require a degree of psychological readjustment similar to that required in moderately severe family or domestic problems, and also found that age, sex and educational level had an effect on the degree of denture acceptance. Other studies have concluded that difficulties of denture acceptance may be influenced by external factors such as the reaction of relatives or friends or the symbolic significance of tooth loss, which may signify ageing, weakness or the loss attractiveness (Straus et al, 1977; Blomberg, 1985; Friedman et al, 1988 a & b; Haugejorden et al, 1993).

It is clear from the literature that physical adaptation to complete dentures presents a complex problem for many patients who may fail to respond to conventional treatment, even with the provision complete dentures that are considered clinically and technically satisfactory (Langer et al, 1961; Carlsson et al, 1967; Bergman & Carlsson, 1972; Smith, 1976). Such patients may be dismissed as having difficult mouths, as being physically unable to adapt to dentures, or as being psychologically maladapted (Zarb, 1982,1983).

Studies have concluded that denture wearing is a matter of skills performance and that once this skill has been acquired, patients rely much less on physical factors such as adhesion and cohesion for denture control (Watt, 1960; Zarb, 1982; Hickey et al, 1985). When these skills start to decline, there is a corresponding reduction in denture function. Many elderly patients have difficulty in coping with complete dentures as the ability of the individual for learning and co-ordination appear to decrease with age, probably owing to a progressive atrophy of the cerebral cortex (Zarb, 1983)

Of course a number of patients never accept removable dentures at all and various anatomical, physiological and psychological factors have been cited as being causes of this (Collett, 1955; Seifert et al, 1962; Carlsson et al, 1967; Carlsson, 1984). It has been reported that 10-15% of patients have a significant degree of difficulty in adapting to complete dentures (Bergman & Carlsson, 1972; Barenthin, 1977; Van Wass, 1984). Of those who have difficulty, it is suggested that the great majority have a genuine prosthetic problem resulting from faults in dentures (Bergman & Carlsson, 1985; Berg, 1988a) or because there is an unsuitable anatomical foundation for denture construction (Atwood, 1971; Tallgren, 1972). With the aid of corrections of prosthetic errors some patients may eventually adapt to dentures, but a number never accept removable dentures despite the best efforts of clinicians and technicians. The causes of this failure are likely to be multi-factorial, but ageing and anatomical, physiological and psychological factors have been identified as common elements (Collett, 1955; Langer et al, 1961; Seifert et al, 1962; Lefer et al, 1962; Carlsson et al, 1967; Bates & Murphy, 1968; Bolender et al, 1969; Atwood, 1972; Tallgren, 1972; Watt & Likeman, 1974; Smith, 1976; Massler, 1980; Berg, 1984; Marbach, 1985).

While many researchers have examined the psychological impact of changes in body features following plastic surgery (Edgerton et al, 1960) and orthognathic surgery (Kiyak et al, 1984,1985), and the psychological effect of loss of body parts in patients following amputations, such as hysterectomies and mastectomies (Jamison et al, 1978), relatively few studies have been focused on the psychological reaction of patients to tooth loss. While some patients view the effect of tooth loss as devastating, other have found its effect to be less intense, probably because edentulism is a relatively common condition in most populations, and tooth loss does not represent a threat to life (Blomberg, 1985; Friedman et al, 1987).

Psychological profile measurement has been proposed as a means of assessing the personality traits of denture patients. Results with different psychological tests have shown that a large number of those patients who have persisting problems with complete dentures have had high neuroticism scores (Sobolik & Larson, 1968; Nairn & Bruenello, 1971; Guckes et al, 1978; Zarb, 1982; Reeve et al, 1984; Gregory et al, 1990). On the other hand, some investigators have found no relationship between psychological measurements and patient satisfaction with complete dentures; for example Smith (1976), who used a shortened version of the MMPI, and Manne & Mehra (1983), who used the Health Locus of Control (HLC). Nonetheless it seems clear that dentists should approach treatment of edentulous patients with the understanding that patients differ in their psychological outlook and that differing approaches are applicable in different situations (Kent & Blinkhorn, 1991).

Many studies have concluded that the psychological difficulties of denture acceptance are influenced by external factors. For instance, a dental clearance may have been carried out without proper psychological preparation of the patient, or the unfavourable reaction of relatives or friends may have an adverse influence, or the symbolic significance of tooth loss, may cause the patient significant psychological distress (Straus et al, 1977; Blomberg & Lindquist, 1983; Haugejorden et al, 1993).

On the other hand, edentulous patients often have unrealistic expectations of the benefits of treatment and this may be a result of dentists' collective failure to inform patients of the biological limitations of the oral cavity and what can reasonably be expected from new dentures (Martone, 1963; Massler, 1976; Rankin and Harris, 1985; Harris, 1994). The successful treatment of the edentulous patient requires not only the use of appropriate techniques and materials, it depends also upon the adaption potential of the patient and on influences such as motivation and behavioural patterns (Breustedt, 1979).

2.2 METHODS OF PREDICTING PATIENT SATISFACTION WITH COMPLETE DENTURES

Researchers and clinicians have found difficulty with practical evaluation of patients' satisfaction with complete dentures and many differing methods of assessment have been used (Berg, 1993). The use of questionnaires is a common approach to subjective evaluation, allowing recording by the patient of their own assessment of oral function. This method of evaluation has been used in both cross-sectional and longitudinal investigations (Karlsson & Carlsson, 1993).

Other methods that have been used to determine patient satisfaction have included the following:

(1) Measurement of patient attitude by means of psychological assessment questionnaires such as the Minnesota Multiphasic Personality Inventory (MMPI), the Conell Medical Index (CMI), the Maudsley Personality Inventory or the Cattell 16-PF test (Bolender et al, 1969; Guckes et al, 1978; Reeve et al, 1984; Vervoorn et al, 1988; Van Wass, 1990 b; Van Aken et al, 1991).

(2) Recording the nature and the frequency of occurrence of patient complaints to identify which are most significant in indicating patient dissatisfaction with complete dentures (Bulman et al, 1968; Nairn & Brunello, 1971; Kotkin, 1985).

(3) Identifying the number of post-insertion denture adjustments (Lefer et al, 1962; Bolender et al, 1969; Silverman et al, 1976).

2.3 DETERMINANTS OF PATIENT SATISFACTION WITH COMPLETE DENTURES

From the literature it would appear that there are a number of different factors which are important determinants of patient acceptance and satisfaction with complete dentures. Van Wass (1990 a & b) has suggested that patient acceptance of dentures is influenced by denture quality, the condition of the intra-oral tissues, the dentist-patient relationship, the patient's general attitude toward denture wearing, the patient's personality and the patient's socio-economic status. Berg (1993) highlighted the importance of demographic variables, previous denture experience and educational background in influencing patients' views of the success of denture treatment.

2.3.1 Denture quality (clinical variables)

The technical quality of complete dentures may be influenced by several factors such as the use of a particular impression technique or a certain type of denture-base material, the setting-up of the teeth in balanced articulation or the choice of a specific artificial tooth. No correlation was found between the technical quality of dentures and the degree of patient satisfaction by Langer et al (1961), Seifert et al (1962), Smith (1976), Berg (1984) and Heyink et al (1986). On the other hand, a moderate positive correlation was found by Bergman & Carlsson (1972) and Van Wass (1990 b) and a strong correlation between denture quality and patient satisfaction with complete dentures was reported by Carlsson et al (1967).

2.3.2 Patient's attitude toward dentures, educational level and counselling

Several reports have shown that many denture wearers have unrealistic expectations of the function of full dentures and it seems reasonable to suggest that patients whose expectations are not met at the end of the treatment are likely to adapt poorly to new dentures (Albino et al, 1984; Davis et al, 1986; Loupe et al, 1988; Goodkind et al, 1988). Bliss (1960) outlined the requirements for effective completion of the educational process in the clinical situation, and suggested that the clinician must be knowledgeable in his subject, should have the ability to transmit this knowledge in simple, clear and understandable terms, should show a sincere interest in those he is trying to educate and should have the ability to inspire confidence. Clinical success, technical proficiency and an understanding of the psychological make-up of patients go hand in hand.

Guckes et al (1978) found that counselling helped patients with emotional problems adapt to new dentures, but the magnitude of these effects was small and was restricted only to those patients with emotional problems. Goodkind et al (1988) and Loupe et al (1988) attempted to modify the knowledge, skills, habits and expectations of denture patients by the use of interviews, demonstrations, video tapes and discussions conducted by a team consisting of a prosthodontist, educational psychologist and oral hygienist. Both studies showed that counselling was successful in modifying patients' knowledge

about denture care and that patients' expectations became more realistic. However Davis et al (1986), who found that patients' expectations of complete denture treatment were unrealistically high, reported that informational video tapes did not significantly alter these expectations. In more general terms, Kent and Blinkhorn (1991) reporting on the effects of educational programmes on oral health found that, while many patients neglect oral health through lack of knowledge, educational programmes have little direct effects on this.

2.3.3 Dentist-patient relationship

Patient acceptance of complete dentures has been found to improve significantly if patients were encouraged to take part in decisions about the aesthetics of the dentures. Under these circumstances patients were more satisfied with treatment and had fewer complaints and post-adjustment visits (Lefer et al, 1962; Collett, 1969). Hirsch et al (1972) allowed patients the opportunity to choose the arrangement of anterior teeth from four different designs at the wax trial stage in denture construction. However they did not give patients the arrangement of teeth they had chosen. All patients reported being satisfied with their dentures, indicating that a crucial component in patient acceptance of dentures was their involvement in the process of selection of teeth, not the aesthetic qualities of the denture they had received. Hirsch et al (1973) also found that patients treated in a non-authoritarian manner were more likely to be satisfied than those treated in an authoritarian manner. It seems clear that effective use of communication skills is the great importance in the successful management of edentulous patients.

2.3.4 Socio-economic variables

Studies of socio-economic status of patients have shown that the frequency of edentulousness and wearing of complete dentures is linked closely with factors such as income, social class, marital status, retirement, loss of a spouse, admission to residential institutions and level of education (Todd & Walker, 1980; Kiyak et al, 1990). While it has been hypothesised that social factors might also influence patient acceptance and satisfaction with complete dentures, Langer et al (1961), Carlsson et al (1967), Breustedt (1979), Berg et al (1985) Kalk & de Baat (1990) and Haugejorden et al (1993) all found that social variables have little influence on denture acceptance.

2.3.5 Oral condition

It is a widespread problem in edentulous patients that the alveolar and basal bone continues to resorb. The variation in magnitude of alveolar ridge resorption in edentulous patients may be owing to a history of advanced periodontal disease or early loss of natural teeth, or it may be related to factors such as ageing, genetic background or hormonal and metabolic disturbance. This resorption is more marked in women than in men, and usually is more severe in the mandible than in the maxilla. However, there is also a considerable variation between individuals and as well as between different areas in the same mouth (Carlsson & Persson, 1967; Atwood, 1971; Watt & Likeman, 1974). Dentures constructed on severely resorbed alveolar ridges tend to show little resistance to lateral displacing forces, and as a consequence retention and stability are likely to be compromised. The deterioration in stability of dentures may be aggravated by a decrease in the degree of the resilience of the mucoperiostium that frequently accompanies such resorption (Tallgren, 1972; Atwood, 1971). Massler (1980) pointed out that increased tissue fragility and diminished quality and quantity of saliva diminish tissue tolerance even to well constructed dentures.

However, it has been shown that variations in the anatomy of the denture supporting structures may have little significant effect on patient satisfaction with complete dentures (Seifert et al, 1962; Makila, 1975; Berg, 1984), and many studies have indicated the absence of any correlation between patient satisfaction with complete dentures and the condition of the oral cavity with respect to ridge form, the volume of saliva present and degree of tissue resilience (Carlsson et al, 1967; Michman & Langer, 1968). It has been suggested that individuals may compensate for the deterioration which occurs in intra-oral conditions, as patients who have been edentulous for a long time often are completely satisfied with denture function (Sheppard et al, 1972).

2.3.6 Demographic variables (adaptability)

With advancing age the adaptive capacity of individuals tends to deteriorate. Sensory feedback from the oral structures declines and the muscular capacity of the masticatory system deteriorates (Breustedt, 1979; Kiyak et al, 1990). Makila (1974 b) reported that patients under 65 years of age were more capable of adapting to new dentures than those over 65 years and elderly patients exhibited a lesser degree of denture acceptance and required more post-insertion adjustment visits than younger patients. However, on the other hand, a great number of studies have reported no detrimental effect of age in denture acceptance (Bergman & Carlsson, 1972; Manderson & Ettinger, 1975; Guckes et al, 1978; Norheim & Valderhaug, 1979; Berg, 1984; Vervoorn et al, 1988; Weinstein et al, 1988).

Female patients may be more sensitive about their appearance than male patients and as a result may have greater psychological problems in adapting to denture wearing (Barenthin, 1977; Haugejorden et al, 1993). Silverman et al (1976) and Haugejorden et al (1993) have claimed that men accepted dentures more readily than women, providing higher morale and self-image scores while, conversely, Sheppard et al (1972) reported that women were more easily pleased than male patients. Other studies have reported no differences between these two groups (Langer et al, 1961; Seifert et al, 1962; Carlsson et al, 1967; Makila, 1974 a; Vervoorn et al, 1988).

2.3.7 Previous denture experience

Collett (1961) and Seifert et al (1962) have indicated that the way patients have adapted to previous dentures may indicate how they will adapt to a new one, and emphasised the importance of previous denture experiences in the development of psychological adaptation following construction of replacement dentures. Seifert et al (1962) also found that patients with previous positive experience of wearing dentures were likely to be more satisfied with new dentures than those with previous traumatic experiences. On the other hand, the correlation between patient acceptance of new dentures and the number of years of previous denture experience was found to be weak by Michman & Langer (1968), Berg (1984) and Van Wass (1990 a).

2.3.8 Oral Stereognosis

Some investigators have undertaken studies to determine possible barriers to adaptation to complete dentures. Such barriers might include a limited ability of patients to recognise and discriminate the shape of small objects placed in the mouth; oral stereognosis or oral perception (Berry & Mahood, 1966). Some authors have hypothesised that patients with a high level of oral perception should be more intolerant to small errors in denture construction, than patients with a lower level of oral perception. This assumption has been investigated by Van Aken et al (1991) who found no positive correlation between oral perception and patient acceptance and satisfaction with dentures. In other studies edentulous patients who reported post-insertion denture problems were scored at high levels for oral perception, in comparison with those without such denture problems (Berry & Mahood, 1966; Litvak et al, 1971).

Many studies have been carried out to determine tactile sensibility by examining the ability of patients to recognise and discriminate test pieces placed between antagonistic teeth. Wearers of complete dentures have been found to have a tactile occlusal threshold six times greater than subjects with a natural dentition (Siirila & Laine, 1969). A study by Lundqvist & Haraldson (1984) was undertaken to assess and compare occlusal perception of thickness in patients with fixed bridges supported by osseointegrated implants, subjects with a natural dentition and complete denture wearers. Occlusal perception was not dependant upon the age or sex of the subjects tested, and did not appear to fluctuate in different areas of the mouth in individual subjects. However, the lowest tactile sensation thresholds were found among the subjects with natural dentitions who could perceive with a thickness of 20 micrometers. Implant patients displayed an average perception thickness of 50 micrometers and the highest threshold levels were found among denture wearers, 100 micrometers. It has been suggested that the absence of periodontal receptors around the dental implant fixtures resulted in reduced tactile sensibility in comparison with natural teeth (Jacobs & Van Steenberghe, 1991).

2.3.9 Patients' personality or the psychological make-up of patients

For many years clinicians and researchers have studied the influence of personality traits on patient acceptance of complete dentures. In general two approaches have been used to identify the patient's personality and its effects on the outcome of dental treatment. The first involves the use of psychological tests such as the Minnesota Multiphasic Personality Inventory [MMPI] (Hathaway & McKinley, 1943), the Cornell Medical Index [CMI] (Broadman et al, 1949), the Cattell's 16-PF test (Cattell et al, 1995) and the Maudsley Personality Inventory (Eysenck & Eysenck, 1991), with psychological assessment carried out by expert psychologists. This allows assessment of various measures of personality, such as extroversion, introversion, and neuroticism (Bolender et al, 1969; Smith, 1976; Guckes et al, 1978; Baer et al, 1992). The second approach involves the use of questionnaires, interviews and the investigation of dental and medical histories to elicit information related to patients' previous experiences and their expectations related to current dental treatment (Collett, 1961; Langer et al, 1961; Seifert et al, 1962; Carlsson et al, 1967; Smith, 1976; Guckes et al, 1978; Berg, 1984; Berg et al, 1986; Van Wass, 1990 b; Vervoorn et al, 1991; Baer et al, 1992).

Many studies have been carried out to determine the influence of personality, by relating factors such as neuroticism, extroversion, introversion, depression and anxiety to the acceptance of dentures. Results from many of these tests have indicated that personality factors appear to have little or no influence on patient satisfaction with complete dentures (Collett & Briggs, 1955; Langer et al, 1961; Seifert et al, 1962; Guckes et al, 1978; Berg et al, 1986; Van Wass, 1990 b; Vervoorn et al, 1991; Baer et al, 1992).

2.4.SATISFACTION WITH IMPLANT-SUPPORTED PROSTHESES

According to Albrektsson et al (1987), 20-25% of the world total adult population is edentulous, and approximately two million people lack natural teeth in one or both jaws in Sweden. In the UK 26% of the population over 16 years of age is edentulous (Office of Population Censuses and Survey, 1985) and in the USA the edentulous population is in excess of 20 million. For many patients the loss of even a single tooth is an event which may lead them to seek dental care in order to restore masticatory function, normal speech, and an acceptable appearance.

Until recent times the treatment of edentulous patients was undertaken almost exclusively by the provision of conventional removable dentures, although there have been well documented attempts to improve the condition of the edentulous mouth through the use of surgical ridge augmentation procedures with bone grafts or the use of pre-prosthetic surgery techniques such as vestibuloplasty. These procedures have been unpredictable in terms of clinical success and patient satisfaction (Miller, 1971; Hopkins, 1980; Fazili et al, 1981; Stoelinga et al, 1983; Zarb, 1983). Treatment by the provision of conventional dentures has to some extent provided a reduction in the disability and handicap of edentulism, but has not fully met the needs of all patients. Poor stability, especially of mandibular complete dentures, has contributed to considerable problems for many patients (Bergman & Carlsson, 1985; Zarb, 1985).

Rehabilitation with rudimentary forms of dental implant has been attempted with limited success over many years, and it is only with the introduction of osseointegrated oral implants (Branemark et al, 1969,1977) that predictably high success rates have been achieved with this form of treatment (Adell et al, 1990). Because of the difficulties encountered by edentulous patients, the successful use of osseointegrated implant prostheses has been one of the most important advances in dentistry in recent times, of particular benefit in patients with poorly formed denture supporting tissues or for those who have functional or psychological impairment following conventional prosthodontic treatment (Blomberg, 1985; Zarb, 1985; Albrektsson et al, 1987). For edentulous patients two approaches to implant treatment are possible. Implants can be used to provide retention and stability for an overdenture by means of mechanical attachments such as ball attachments, magnetic attachments or bar attachments. Alternatively, when

a sufficient number of fixtures is available, a fixed prosthesis becomes an option.

As previously noted, the loss of natural teeth and the inability to adapt and function well with conventional complete dentures may result in psycho-social problems. In the early 1970s, when osseointegrated implant techniques were at a developing stage, it was generally accepted that patients with psychological problems should be excluded from implant treatment because of concerns that additional psychological problems, which could have adversely affected the successful outcome of treatment, may have arisen. However, Blomberg (1992) suggested that in many cases the perceived psychological contra-indications were only relative, and that such patients required only good support from a psychologist or clinical psychiatrist for dental implant treatment to be successful.

2.4.1 Patient attitude toward dental implants

Dissatisfaction with conventional dentures is an important factor encouraging patients to seek implant treatment, and in several studies the motives for patients seeking implant treatment have been examined.

Kiyak et al (1990) found that lack of stability of an existing denture during function was of major concern, while speech and general appearance were of less concern. Akagawa et al (1988) found a significant relationship between dissatisfaction with stability of existing complete dentures and a positive attitude of patients towards implant therapy, with variables such as speech and appearance not closely linked to patient motivation. Grogono et al (1989) reported that 70% of patients, interviewed before dental implant treatment, were seeking an improvement of chewing ability, 36% were hoping to improve appearance, 44% to improve self-confidence, while 56% were dissatisfied with their present removable dentures mainly for psychological reasons.

There are many barriers that may deter patients from preceding towards implant treatment. Akagawa et al (1988) found that the main reasons given by patients were the cost of treatment and fear of surgery. Kiyak et al (1990) also found that fear of surgery was a major consideration, along with concerns about post-operative problems and complications. Zimmer et al (1992) found that advancing age was a common reason for patients to rule out implant treatment and that the high costs involved discouraged many patients.

2.4.2 Satisfaction with fixed implant-prostheses

Many clinicians prefer the use of implant-borne fixed-prostheses to implant-retained overdentures, due to the belief that fixed-prostheses best simulate the natural teeth, that they provide the greatest chewing efficiency and that they result in more patient satisfaction (Hobo et al, 1990; Zarb and Schmitt, 1990; Naert et al, 1991). Most studies investigating patient satisfaction with dental implants have focused on fixed prostheses and it has been shown that this approach to Prosthodontic treatment has fulfilled both functional and psychological needs for many patients (Blomberg & Lindquist, 1983; Albrektsson et al, 1987; Hoogstraten & Lamers, 1987; Gregory et al, 1990; Kiyak et al, 1990; Kent & Johns, 1991, 1993, & 1994).

Blomberg & Lindquist (1983) assessed the psychological reaction of patients towards Edentulousness and to treatment with osseointegrated fixed prostheses, studying two groups matched with regard to number (26 patients for each group), sex and degree of ridge resorption. The patients in both the control and experimental groups had 10 years denture experience. The Eysenck Personality Inventory and dento-social questionnaires were used to assess the reaction towards treatment. Both groups had been provided with new optimised conventional denture and two months later were assessed by the use of questionnaires. It was shown that two of the twenty-six patients in the experimental group were satisfied and did not proceed to further treatment. The experimental group were treated using osseointegrated fixed-bridge prostheses in the lower jaw, opposed by maxillary complete dentures. The experimental group was assessed psychologically by self-assessment questionnaires three months after implant treatment in the mandible, and again after two years when implant restoration had been undertaken in the maxilla. It was shown that patients felt that the osseointegrated prostheses were comparable with their dentitions. Moreover, patients stated that their self-confidence, appearance and their social activities improved after implant treatment. There is no record of follow-up of the control group and it is not clear what benefits the control group gained in comparison with the experimental group. Similar favourable findings on the outlook of patients treated with implant-supported bridges have been reported with the use of self-administered questionnaires in short-term studies by Lindquist & Carlsson (1982) and Zarb & Symington (1983) and in long-term prospective studies by Albrektsson et al (1987) who undertook a study of patients treated with osseointegrated fixed prostheses

over the period from 1965 to 1978. Albrektsson et al reported that 82% of patients were satisfied with the function of their prostheses and they regarded their implant prosthesis as "part of their own body" instead of as a foreign object. The vast majority of patients (97%) reported an improvement in social activity.

Gregory et al (1990) supported the findings of these studies when they reported on a follow-up of 13 patients over three years using the Cattell's 16-PF test and subjective general dental questionnaires. Patients were treated with implant-borne fixed-prostheses in the mandible and conventional complete dentures in the maxilla. Of six patients who showed a high level of anxiety prior to implant treatment, five were assessed as normal after implant treatment. The majority of patients showed a significant improvement in well-being, social activity and were more secure after treatment.

Kiyak et al (1990) conducted a longitudinal study of 39 patients who had an osseointegrated fixed prostheses in one or both jaws. Psychosocial activity, oral function, patients' expectations, experiences of difficulties with surgery, body-image and neuroticism were assessed by interviews pre-operatively then followed-up by the use of self-assessment questionnaires and other psychological tests such as Eysneck Personality Inventory and Tenness Self-Concept Scale. There was a significant improvement in all tested variables other than self-esteem. Patients who scored at a high level on neuroticism in the Eysneck Personality Inventory showed more post-surgical discomfort and less satisfaction with treatment than average. The findings of this study supported Blomberg & Lindquist (1983), Blomberg (1985), Albrektsson et al (1987), Grogono et al (1989), Van Wass & Bosker (1989) whose patients had been evaluated with the use of self-administered dento-social questionnaires.

Kent & Johns (1991) carried out a prospective longitudinal study on the psychological effects of implant treatment. Two groups were studied, the control group consisting of 18 patients who were found to be unsuitable candidates for implant treatment because of anatomical contra-indications and the experimental group (29 patients) each of whom was treated with an implant-borne bridge opposed by a maxillary complete denture. Both groups completed psychological tests such as the General Health Questionnaire, Rosenberg's Self-esteem Scale and the Symptom Check-list Questionnaire, after initial Prosthodontic assessment, then six months after treatment and again two years later. No difference between the two groups was reported at initial assessment. There was a

substantial improvement in well-being and in social relationships following implant treatment, whereas the control group showed an increase in distress and no change in social activities on assessment in General Health Questionnaire scores. It was considered that the control group may have returned to a previous baseline level of psychological disturbances or their unsuitability for treatment may have led the patients to consider themselves rejected with adverse effect on their psychological profile. A further study was conducted in 1993 by Kent & Johns with a follow-up period over two years, with a comparison control group of 61 dentate patients who were not in need of implant treatment. The findings were similar to the 1991 study. Another study was carried out by Kent & Johns (1994) using the same psychological measures as in the 1991 and 1993 studies, but with an appropriate comparison control group consisting of complete denture patients seeking improvement of their existing dentures, which was achieved either by relining or renewing. There was a decline in psychological distress for implant patients, but no change for the complete denture patients.

Two main conclusions can be taken from Kent and Johns studies of 1991, 1993 and 1994. Implant treatment proved to be an effective option as far as reducing psychological distress and other disabling symptoms, compared to conventional treatment, and it was apparent that implant treatment had no effect on patients' self-esteem.

2.4.3 Satisfaction with implant-retained overdentures

Considerable research has been conducted on the efficacy of dental implants in the areas of osseointegration, implant design, clinical survival rates and bio-compatibility of the implant materials. Many of these studies have evaluated the value of fixed implant-prostheses compared to conventional denture treatment, examining patients' views and reactions. These studies have shown that with implant-supported bridges patient satisfaction was generally high and that patients reported a considerable improvement in quality of life, self-confidence and acceptance of the prostheses as part of themselves (Blomberg & Lindquist, 1983; Blomberg, 1985; Hoogstraten & Lamers, 1987; Kiyak et al, 1990; Kent & Johns, 1991,1993,1994).

Fewer studies have investigated the treatment outcome with regard to patient satisfaction with implant-retained overdentures, despite the fact that implant-retained overdentures have become a successful alternative treatment in the rehabilitation of edentulous patients with long-standing problems with conventional dentures (Engquist, 1985; Naert et al, 1988,1991; Quirynen et al, 1991; Meriscke-Stern, 1990). When anatomical or financial considerations limit the number of implants that can be inserted, or when aesthetics and speech may be impaired by the space between a fixed implant-prosthesis and the residual ridge, the use of implant-retained overdentures many have particular value (Lekholm & Zarb, 1985; Desjardins, 1992; Hobo et al, 1990).

A number of studies have examined patient satisfaction with implant-retained overdentures (Van Wass & Bosker, 1989; Clancy et al, 1992; Johns et al, 1992 a & b; Cune et al, 1994 b; Wismeijer et al, 1992,1995,1996; Burns et al, 1995 a & b; Boerrigter et al, 1995; Humphris et al, 1995; Geertman et al, 1996 b; Tang et al, 1997) and it has been shown that the vast majority of patients treated with implant-retained overdentures have given a level of response comparable to that for patients treated with implant-supported fixed-bridges. Improvements in oral function and in the psychological outlook of patients have also been reported (Engquist et al, 1988; Naert et al, 1988; Mericske-Stern, 1990; Quirynen et al, 1991; Mericske-Stern & Zarb, 1996; Boerrigter et al, 1995; Wismeijer et al, 1995, 1996; Geertman et al, 1996a & b; Tang et al, 1997).

Subjective assessment of patient satisfaction with mandibular implant-retained overdentures supported by Titanium Plasma Screw (TPS) and ITI dental implants was carried out by Wismeijer et al (1992,1995) in 64 edentulous patients. Subjects were

evaluated on their experiences of treatment up to 6 years after implant placement and 95% of patients were satisfied with their prostheses with respect to dental and psycho-social functions. In a further study with a follow-up period of 19 months, Wismeijer et al (1996) studied satisfaction in 110 edentulous patients treated with ITI osseointegrated dental implants, using three different treatment strategies; a mandibular overdenture supported by two implants with ball attachments, two implants with a straight bar and four implants interconnected by an angulated bar attachment. Patients' opinions on their overdentures, oral function and social activity were evaluated subjectively by means of questionnaires. Almost all patients were generally satisfied with their overdentures with respect to oral function, comfort and social rehabilitation. No significant difference was found between the three treatment strategies. These findings are in agreement with those of Burns et al (1995 b), who found that patients were satisfied with different methods of attachment, but a strong preference was noted for the stud attachments over the magnets with respect to retention and stability. In the study of Burns et al (1995 b) patients were again evaluated subjectively by the use of self-assessment questionnaires.

De Grandmont et al (1994) and Feine et al (1994) studied mandibular implant-supported fixed bridges and implant-retained overdentures in a within-subjects crossover comparison investigation. Subjects rated their perception of conventional complete dentures and implant prostheses using a Visual Analogue Scale (VAS) with consideration of general satisfaction, speech, aesthetics and the ability to chew different types of food. One group received a fixed prosthesis first, while the other group received an implant-retained overdenture. After two months of adaptation, functional and psycho-social assessments were carried out with the use of subjective questionnaires. The prostheses were then changed around, and the same measurements repeated. It was reported that most patients were quite satisfied with both treatment concepts compared to their original conventional dentures for all tested variables, although some patients stated that their ability to chew hard foods was better with the implant-supported fixed prostheses than with the implant-retained overdentures. Otherwise, there was no difference in the level of satisfaction with the two types of implant prosthesis, although there was a tendency for the implant-retained overdentures to be favoured by older patients owing to accessibility for cleaning. Similar findings were reported by Tang et al (1997) using the same methodology and socio-dental measurements as De Grandmont et al (1994) and Feine et al (1994), but the within-

subject comparison was between a mandibular cantilevered bar supported by 4 implant fixtures and a hybrid overdenture supported by two implants. It was reported that patients preferred the bar prostheses over the hybrid overdenture with respect to stability, retention, chewing, comfort, aesthetics and general satisfaction. Ease of cleaning and speech were rated significantly better with hybrid overdentures.

In a multicentre study by Boerrigter et al (1995) a comparative investigation in two groups of patients having long-standing problems with conventional mandibular dentures was carried out. The first group (132 patients) was treated with mandibular implant-retained overdentures anchored by implant fixtures. Three implant systems were used; Branemark, IMZ and the Trans-Mandibular Implant system (TMI). The overdentures were opposed by maxillary complete dentures. Patients in the control group (18 patients) were provided with optimised complete dentures in both jaws. The treatment outcome from patients' point of view was evaluated subjectively by the use of self-assessment questionnaires focusing on denture complaints and general satisfaction. It was reported that on evaluation after one year, patients treated with implant-retained overdentures appeared to be more satisfied than the control group with respect to the measured variables such as denture function, aesthetics, comfort and speech. In a study carried out by Geertman et al (1996 a), the progress of a group wearing implant-retained overdentures (62 patients) supported by Trans-Mandibular Implants (TMI) or IMZ osseointegrated dental implants were compared with a control group (29 patients) who received conventional dentures. Patients were followed-up for one year and assessed using subjective self-assessment questionnaires. There was a significant difference between satisfaction levels for patients with implant-retained overdentures compared to patients who received only conventional complete dentures, but little difference with respect to satisfaction, complaints and subjectively measured chewing ability between the TMI group and the IMZ group.

2.5 AIMS OF THE FIRST PSYCHOLGICAL STUDY

The first psychological present study had two main objectives. The first was to examine a group of twenty edentulous patients in order to measure the immediate effect of implant treatment on the psychological state of the group, the second aim was to examine the group over the longer term, in order to assess whether any initial change observed in psychological profile remained consistent with the passage of time. It was hoped, in this psychological study of edentulous patients undergoing implant treatment, to establish that the psychometric assessment used (Cattell's 16-PF test) would be appropriate for more detailed assessment of treatment outcome following placement of dental implants.

2.6 MATERIALS AND METHODS

2.6.1 Method of assessment

The test used in psychometric screening of the group was the Cattell's Sixteen Personality Factor questionnaire (16-PF) which was used at all stages of the investigation

2.6.2 Background of the psychological test used (Appendix 2.1)

The Cattell's 16-PF test was developed in 1945 by Dr Raymond Cattell as one of the first objective tests, based on scientific research, to measure the basic dimensions of human personality. It was modified and revised in 1956, 1962, 1967-1969 and 1993 and has wide acceptance as a well-researched measure of normal personality (Schuerger, 1992). It consists of 16 primary-factor scales and five global-factors (second-order factors). Both the primary and the global factors measure the same personality characteristics, but at two levels of specificity.

In the first instance Cattell analysed the entire range of personality-trait descriptors in the English language (every word that pointed to a description of personality, e.g. calm, cool, angry, nervous, quiet, etc). He identified 17,955 trait words. Following a long series of factor analytical studies of behaviour ratings and questionnaire data, in 1946 Cattell reduced those personality descriptors to 16 basic dimensions, which he called the primary factors of the 16-PF test. The fifth edition of the 16 PF-test was published in 1995 (Cattell et al, 1995) and incorporated an updating and simplification of the

language used, removed content that might suggest gender, race or disability bias and made the content more easily translatable into languages other than English (Cattell et al, 1995).

The Cattell 16-PF test was designed to measure the personality characteristics of an individual and the descriptors of the primary factor scales have been subject to many changes since inception. For example, the primary factors were initially identified by a letter (i.e. A to O, and Q1,Q2,Q3,Q4) and the scales for each factor were initially described by an original term devised by Cattell. For example the original description for factor A with low score, was Sizothymia (Cattell, 1945). After revision the primary factors were described with adjectives such as cool, reserved, detached etc to simplify the language for more general understanding (Cattell et al, 1980), and in the fifth edition further changes were introduced to improve and simplify readability, and to help clarify the meaning of the primary factors. The primary factors continued to be called by the same letters, but with new adjective descriptions **(Table 2.1)**.

Factor	Description	Factor	Description
A	Warmth	**L**	Vigilance
B	Reasoning	**M**	Abstractedness
C	Emotional-Stability	**N**	Privateness
E	Dominance	**O**	Apprehension
F	Liveliness	**Q1**	Openness-to-Change
G	Role-Consciousness	**Q2**	Self-Reliance
H	Social-Boldness	**Q3**	Perfectionism
I	Sensitivity	**Q4**	Tension

Table 2.1: The primary factors of the Cattell's 16-PF test

In another change, the adjectives *suspicious* and *distressful,* that had previously described Factor L, were seen as less acceptable and replaced with a new heading, vigilance. The global factors (*extraversion, anxiety, tough-mindeness, independence, and self-control*) were developed through analysis of the primary factors, using statistical methods. For example, *extraversion* can be extracted from those primary scales having high loading on factors such as *warmth* (A), *liveliness* (F), *social boldness* (H), *privateness* (N), and *self-reliance* (Q2). These principles applied to the development of each of the other global factors. In the fifth edition, the global factors featured show only slight changes from the earlier editions of the 16 PF-test. For example in the earlier edition, *tough-mindedness* was called *tough-poise*, but this was

changed in the fifth edition to reflect the prominent contribution of *sensitivity* factor (I). The factor denoting *self-control* was initially called *control*. The prefix *self* was added to denote this scale's focus on the control of individual's own thoughts, feelings and behaviour, rather than those of others (Cattell et al, 1995). Four formats of the questionnaire are available (A,B,C,D), in more than 40 languages, and all are presented and scored in the same way. Format C is the shortest and uses fewest questions to tap each of the 16 factors. This version has been considered the most appropriate form for use in dental situations (Reeve et al, 1982, 1984).

The 16 PF-test has been used in research and applied settings, including industrial, clinical, and educational applications. Its use has resulted in a wide range of prediction equations for criteria such as leadership, interpersonal skills, and psychological adjustment (Cattell et al, 1980; Guastello & Rieke, 1993; Russell & Karol, 1994). Reeve et al (1982) were among the first to use the Cattell 16-PF test in dentistry; they evaluated the responses of edentulous patients to complete denture treatment, and examined if variations in personality could influence the outcome of treatment. Reeve et al (1984) again used the test in the assessment of pre-prosthetic surgery patients to see whether such a test identified any personality traits that distinguished satisfied from dissatisfied patients and identified if such traits would indicate pre-treatment the likelihood of an operation having a satisfactory outcome from the patient's point of view. In 1990, Gregory et al conducted a clinical study using the test to assess the psychological effects of fixed-prosthesis construction, following implant placement.

The questionnaire (Format C) consists of 105 informally worded questions and the responses yield a raw score on 16 independent bi-polar scales. These raw scores are obtained using an answer-key stencil sheet. The raw scores are converted into standard scores (sten scores), with the use of the appropriate norm-tables for the general population. In the present study Form C, for both males and females, from the Tabular Supplement No.2 of the 16-PF Handbook was used. Each raw score was converted to its sten score and plotted into sten profiles to indicate the position of each on the low and high score description for each factor.

2.6.3 Patient selection

Twenty edentulous patients from the waiting list of the Department of Prosthodontics at Glasgow Dental Hospital & School were asked to participate in the study. All had been referred for possible implant treatment following long-standing problems with conventional mandibular complete dentures. The patients' complaints included instability of the lower denture, pain under dentures and difficulties with eating and speaking. A number complained of the adverse effects of poor dental function on social interaction.

There were four male and 16 female patients in this study. The average age of the group was 53 years, with a range of between 34 and 77 years (**Table 2.2**). Seventeen of the patients had been edentulous for more than ten years, and the average time that the group were edentulous was 13 years with a range of between 8 and 18 years.

Age (years)	Female	Male
30-39	1	0
40-49	6	1
50-59	6	0
60-69	2	2
70-79	1	1
Total	**16**	**4**

Table 2.2: Sex and age distribution of experimental group

2.6.4 Treatment protocol

A total of 73 ITI® titanium transmucosal dental implants were installed for the patients in this group. The number of fixtures placed, the distribution of fixture type and fixture length, and the method of restoration used for the finished prostheses, are shown in **Tables 2.3, 2.4,** and **2.5**. The overdentures were retained by stud or bar attachments and care was taken to optimise the standard of clinical and technical technique in both the surgical and the prosthetic phases of treatment.

Number of Patients	Number of Fixtures
2	2
3	3
15	4

Table 2.3: Distribution of fixtures

Type of Fixture		Type of Retention	
H.C*	35	Stud†	3
H.S**	38	Bar‡	17

Table 2.4: Fixture type and method of denture retention.
***H.C**, Hollow-Cylinder implant.
****H.S**, Hollow-Screw implant.
†**Stud**, Mandibular overdenture retained by retentive anchor stud attachment.
‡**Bar**, Mandibuar overdenture retained by soldered bar and clip attachment.

Hollow-Cylinder		Hollow-Screw	
Length	No.	Length	No.
8-mm	8	8-mm	11
10-mm	20	10-mm	11
12-mm	7	12-mm	16

Table2.5: Fixture length distribution

2.6.4.1 Pre-implant assessment

Prior to acceptance for implant treatment, the design of existing dentures had been scrutinised and, where appropriate, replacement conventional dentures had been made. All 20 subjects completed the Cattell's 16-PF psychological test, patients taking approximately 40 minutes to complete this 105-questions.

2.6.4.2 Immediate post-implant assessment.

Regular clinical reviews were carried out following treatment. There was only one implant fixture failure, and this occurred within the healing phase before denture construction. Initial post-treatment assessment using the Cattell's 16 PF-test was carried out three months after the patients started to wear the implant-retained mandibular overdentures. All twenty patients in the study completed the initial post-treatment questionnaires.

2.6.4.3 Late post-operative assessment.

After completion of treatment and the initial review and assessment stages, all twenty patients attended for routine clinical review and hygienist appointments as required. Formal assessment by psychological profile analysis was repeated a minimum of three years after implant placement. The Cattell's 16-PF test was repeated to allow comparison with pre- and immediate post-treatment Cattell's 16-PF tests. This gathering of clinical and psychological data was undertaken before and immediately after implant treatment and repeated after three years to allow assessment of implant-retained overdenture treatment, with respect to psychological function in this group.

2.7 RESULTS

In the Cattell 16-PF questionnaire, a total of 16 primary factors of personality were assessed after converting the raw scores for the patients as a group into sten scores. Scores below 4 count as low range values, above 7 count as high range values and scores between 4 and 7 are normal. The sten scores for the three assessments are shown in **Table 2.6, 2.7 and 2.8.**

FACTOR	STEN SCORE									
	1	2	3	4	5	6	7	8	9	10
Warmth (A)	0	0	2	4	5	3	2	2	2	0
Reasoning (B)	0	3	3	8	1	3	0	1	1	0
Emotional-Stability (C)	0	1	2	7	1	4	1	3	1	0
Dominance (E)	0	2	1	8	2	1	3	1	2	0
Liveliness (F)	1	2	3	2	1	11	0	0	0	0
Role-Consciousness(G)	0	1	0	3	1	3	4	2	3	3
Social-Boldness (H)	0	0	4	3	6	1	0	2	3	1
Sensitivity (I)	0	0	0	8	6	2	4	0	0	0
Vigilance (L)	0	3	0	5	5	3	3	0	0	1
Abstractedness (M)	1	0	1	2	1	5	10	0	0	0
Privateness (N)	1	0	3	1	1	2	6	4	1	1
Apprehension (O)	0	0	2	1	2	4	6	4	0	1
Openness To Change (Q1)	2	1	0	6	5	2	4	0	0	0
Self.Reliance (Q2)	0	0	1	1	1	9	1	3	3	1
Perfectionism.(Q3)	0	0	2	0	5	4	4	2	2	1
Tension (Q4)	0	0	2	1	2	2	10	0	2	1

Table 2.6: The Cattell's sent scores for pre-implant treatment.

FACTOR	STEN SCORE									
	1	2	3	4	5	6	7	8	9	10
Warmth (A)	0	0	3	6	2	3	3	1	2	0
Reasoning (B)	0	1	5	3	3	4	0	3	1	0
Emotional-Stability (C)	0	2	2	8	2	2	1	2	1	0
Dominance (E)	0	2	3	7	0	2	2	3	1	0
Liveliness (F)	2	3	3	5	1	3	1	1	1	0
Role-Consciousness.(G)	1	0	1	3	1	3	4	2	3	3
Social-Boldness (H)	1	1	5	1	4	2	1	3	0	2
Sensitivity (I)	0	1	0	8	3	3	3	2	0	0
Vigilance (L)	1	1	2	4	4	5	1	2	0	0
Abstractedness (M)	0	1	1	6	2	3	5	1	1	0
Privateness (N)	0	1	4	2	6	0	3	2	0	2
Apprehension (O)	0	0	5	0	6	1	2	2	2	2
Openness To Change (Q1)	0	3	3	4	5	2	3	0	0	0
Self.Reliance (Q2)	0	1	1	1	0	12	3	2	0	0
Perfectionism.(Q3)	1	0	0	0	3	7	3	3	3	0
Tension (Q4)	0	1	1	3	3	3	5	2	2	0

Table 2.7: The Cattell's sten scores for immediate post-implant treatment.

FACTOR	STEN SCORES									
	1	2	3	4	5	6	7	8	9	10
Warmth (A)	0	0	5	3	1	5	4	2	0	0
Reasoning (B)	0	2	6	3	2	3	0	3	1	0
Emotional-Stability (C)	0	4	1	6	4	2	2	0	0	1
Dominance (E)	0	0	2	6	4	4	1	3	0	0
Liveliness (F)	0	2	4	3	1	6	1	3	0	0
Role-Consciousness(G)	0	0	0	2	0	3	3	9	2	1
Social-Boldness (H)	0	1	2	2	6	2	2	3	2	0
Sensitivity (I)	0	1	0	5	4	4	5	1	0	0
Vigilance (L)	0	3	4	5	3	2	2	0	0	1
Abstractedness (M)	0	2	3	2	2	3	8	0	0	0
Privateness (N)	1	2	1	0	3	4	2	5	2	0
Apprehension(O)	1	0	2	2	6	1	4	4	0	0
Openness To.Change (Q1)	2	0	2	3	10	1	1	1	0	0
Self.Reliance (Q2)	0	1	1	1	1	5	5	2	4	0
Perfectionism. (Q3)	1	0	1	3	3	5	3	3	1	0
Tension (Q4)	0	1	2	3	2	4	4	3	1	0

Table 2.8: The Cattell's sten scores for post-implant treatment (after 3-years).

Factor A is a measure of a patient's personality in terms of whether they are reserved or outgoing. Initially the experimental group as a whole was largely within the range of normal with respect to *Factor A*, and this group characteristic persisted throughout the duration of the study. While the overall picture of a normal profile persisted, several patients showed changes such that only one of the four patients with high scores indicating an outgoing personality at initial assessment remained at high values in the final analysis, and five patients had shown a trend towards a more detached personality than average at the final assessment, compared to two initially.

Factor B is a measure of a patient's personality in terms of whether they are concrete or abstract thinking. Pre-operatively twelve of the 20 patients were within the range of normal with respect to *Factor B*, two patients had scores indicating a high level of abstract thinking and six patients had scores indicating a high level of concrete thinking. In the immediate post-operative assessment, the number of patients with normal values reduced to ten, the number of patients who had scores indicating abstract thinking increased to four and patients with scores showing concrete thinking remained unchanged at six. After three years, the number of patients with normal values fell to eight, patients who had high range scores fell to four and those patients with low range scores increased to eight.

Factor C is a measure of a patient's personality in terms of whether they are easily upset (low ego-strength) or calm (higher ego-strength). It was found pre-operatively that thirteen of the 20 patients were within the range of normal, four patients gave scores indicating a high level of emotional stability and three patients had scores indicating low emotional stability. Seven patients showed consistency within the range of normal throughout all three assessments. Of the thirteen subjects showing normal values for *Factor C* at initial assessment, seven remained unchanged throughout the study. Six patients fluctuated, four showing less emotional stability and two showed normal values at the final assessment.

Factor E is a measure of a patient's personality in terms of whether they are submissive or assertive. Pre-operatively fourteen subjects were within the range of normal, three patients had scores indicating higher than average submissiveness and three patients had scores showing a stubborn and dominant personality. There was a trend from submissiveness at initial pre-implant assessment, to a more normal profile in the last post-operative phase. Three patients in the pre-treatment phase and five in the immediate post-treatment phase who showed an a high level of submissiveness showed a normal value in the final analysis.

Factor F is a measure of a patient's personality in terms of whether they are prudent or impulsive. Pre-operatively fourteen patients were within the range of normal with respect to *Factor F*, six patients had scores showing a prudent characteristic and no patient had scores showing an impulsive personality. There was a slight tendency for the group to become more impulsive in the final assessment. *Factor G* is a measure of a patient's personality in terms of whether they are expedient/disregard rules or conscientious/meticulous. With respect to *Factor G* it is apparent that the group tended towards the rule-consciousness characteristic throughout all three assessment.

Factor H is a measure of a patient's personality in terms of whether they are shy/timid or bold/spontaneous. Pre-operatively ten patients had values within the range of normal, six patients gave scores showing a characteristic of social boldness, four patients had scores indicating a shy personality. In the immediate post-operative assessment, the number of patients with normal values fell to eight, patients with scores indicating social boldness was reduced to five and the number of patients with scores indicating a

shy personality increased to seven. Three years post-operatively, the number of patients with values within the range of normal was twelve, the number of patients showing social boldness was five and the number of patients with low scores the characteristic of shyness was three.

Factor I is a measure of a personality in terms of whether a patient is self-reliant or over-protected. The group as a whole showed a personality trait which was slightly more sensitive than average, and there was little change in this personality characteristic in the duration of the study. *Factor L* is a measure of a patient's personality in terms of whether they are trusting or suspicious. At initial assessment the group as a whole tended slightly towards a personality characteristic of being slightly more trusting than normal and this trend became stronger in the last post-assessment phase when seven patients with values within the normal range at the initial assessment showed values indicating trusting personality characteristics.

Factor M is a measure of a patient's personality in terms of whether they are practical or imaginative. Pre-operatively eighteen patients were within the range of normal with respect to *Factor M*, two patients gave low scores indicating a high level of practicality. In the immediate post-operative assessment, the number of patients with values within the range of normal for fell to sixteen, two patients had high scores showing a higher level of imagination and the number of patients with low scores, remained unchanged at two. In the post-operative assessment after three years, the number of patients with normal values for *Factor M* fell to fifteen, the number of patients who had high scores indicating a higher level of imagination returned to baseline value of zero and the number of patients who had low scores indicating practicality was increased to five. Twelve patients showed consistency for *Factor M* in all three assessments all within the range of normal, and six individuals with initial values within the range of normal fluctuated in subsequent assessments. *Factor N* is a measure of personality in terms of whether a patient is forthright or discreet. With respect to *Factor N*, at the initial assessment the group as a whole showed a slight tendency towards a high degree of privatisation, with an even balance between the two extremes of this personality trait at the final post-operative assessment. *Factor O* is a measure of a patient's personality in terms of whether they are secure or insecure. There was a strong bias towards the personality characteristic of having an insecure nature. This shifted by a moderate

degree towards a more normal profile in the post-treatment assessments, although an overall tendency towards insecurity remained within the group.

Factor Q1 is a measure of a patient's personality in terms of whether they are conservative in outlook or open-to-change. At the initial assessment the group as a whole showed mainly normal values with respect to this personality characteristic which persisted throughout the study. *Factor Q2* is a measure of a patient's personality in terms of whether they are group oriented or self-sufficient. At initial evaluation most of the group showed normal values for this personality characteristic, but there was a trend towards self-sufficiency with treatment. *Factor Q3* is a measure of personality in terms of whether a patient is undisciplined or perfectionist in outlook. At initial assessment it was apparent that the group tended towards the category having a high level of self-control, and while this tendency was increased slightly in the immediate post-treatment assessment, it returned to the baseline level in the final analysis. *Factor Q4* is a measure of a patient's personality in terms of whether they are relaxed or tense. The group as a whole showed a constant normal profile throughout the study with an even balance between the two extremes of this personality trait at the final assessment.

2.7.1 Statistical analysis

The pre-treatment, immediate-post treatment and late post-implant treatment data were subjected to repeated measures analysis of variance on each of the individual sixteen primary factors. The effectiveness of implant treatment on patients' psychological status during the follow-up would be reflected in a significant main effect of time.

The results of the analysis of variance showed that there was no statistically significant change in any of the primary factors in any assessment, although there was an apparent change in Liveliness (F) and Apprehension (O) factors. However, these changes were not statistically significant. The summary data for all primary factors are shown in **Table 2.9**.

Factor	Pre-implant treatment		immediate-implant treatment		Post-implant treatment		*P*-Values
	Mean	S.D	Mean	S.D	Mean	S.D	
Warmth (A)	8.35	2.08	8.50	2.01	8.20	1.79	0.86
Reasoning (B)	3.25	1.65	3.85	1.73	3.70	1.84	0.28
Emotional-Stability (C)	6.50	2.42	6.50	2.50	6.15	2.48	0.80
Dominance (E)	4.85	2.52	4.75	2.63	5.00	1.89	0.92
Liveliness (F)	5.80	2.07	5.20	2.28	6.35	2.37	0.07
Role-Consciousness(G)	8.90	2.40	8.40	2.60	9.15	1.63	0.20
Social-Boldness (H)	6.55	2.76	6.55	3.28	7.20	2.61	0.49
Sensitivity (I)	6.15	1.46	6.40	2.32	6.45	1.82	0.80
Vigilance (L)	5.00	1.95	4.90	1.83	4.30	2.05	0.17
Abstractedness (M)	6.15	1.93	5.90	1.97	5.45	2.09	0.44
Privateness (N)	5.15	2.54	4.65	2.72	5.15	2.64	0.58
Apprehension(O)	7.60	2.46	6.85	3.28	6.10	2.86	0.09
Openness To Change (Q1)	5.85	2.30	5.60	1.70	5.60	1.93	0.79
Self.Reliance (Q2)	5.30	2.36	4.65	1.73	5.35	2.52	0.37
Perfectionism. (Q3)	8.10	1.86	8.38	2.37	7.75	1.94	0.64
Tension (Q4)	6.90	2.10	6.15	2.52	5.95	2.37	0.20

Table 2.9: Statistic summary for the Cattell's 16-PF primary factors.

2.8 DISCUSSION

The main reported study which utilises the Cattell's 16-PF test in a context similar to the present study, and a primary reason for selecting its use in this study, is that published by Gregory et al (1990). Although they reported positively on the use of this test in assessing the suitability of patients for implant treatment and in monitoring treatment outcome, one could criticise the statistical analysis they presented, which failed to take account of the effect of multiple comparisons, increasing the risk of type-1 statistical error (falsely rejecting the null hypothesis).

Despite claims to the contrary, when the data of Gregory et al (1990) were re-evaluated, correcting for the effect of multiple comparisons, there were no significant findings in terms of positive trends for psychometric evaluation before and after implant treatment.

While the present study lacks a control group, the patients' sten profiles allowed comparison with the so-called norms. There were no significant changes in the sten data for the Cattell's 16-PF test over time for any of the factors. While there were weak trends for an increase in liveliness and a reduction in apprehensiveness over time, these

are marginal effects and do not even approach significance if correction is carried out for multiple comparisons. Nevertheless, there were some individual fluctuations over time, it is not possible to discount that these individual fluctuations were other than random occurrences.

2.9 CONCLUSIONS

It was concluded from this study, examining twenty edentulous patients, that any changes in psychological well-being following implant treatment were not evident with the use of the Cattell's 16-PF test. Whether this was because there was no change within the group, or whether the psychological test used was an inappropriate method of gauging it, cannot be identified, but it is unlikely that dental implant treatment would have so radical effect on a patient as to change their personality. It was also concluded that a better psychological insight might be obtained by the use of assessment of emotional state, because this is more likely to show fluctuations and reflect any effect of treatment.

2.10 AIMS OF THE SECOND PSYCHOLOGICAL STUDY

This study is a development of the work described in the first psychological study **(2.5)**. Following-on from that study the procedures for analysis of the psychological status of patients were modified with the use of a different assessment of psychological well-being, known to be sensitive to change in state. It was considered useful, and practical in the dental context where time for assessment is limited, to use an instrument that would provide a global assessment of emotional state, more serious psychiatric disturbance and social functioning.

In this study ten patients were treated initially by provision of optimised conventional dentures followed by the placement of two ITI® implant fixtures in the anterior region of the mandible to provide retention for the otherwise unmodified dentures. Measures to evaluate denture function, patient perception of treatment and psychological status of the ten subjects were undertaken before and after implant treatment.

The aim of the study was to measure the effect of implant treatment on the psychological profiles of the ten subjects by using the Symptom Check-List-90-R test, completed by the subjects after conventional denture treatment and again after the conversion of the conventional dentures to implant-retained overdentures. In this chapter, the findings with respect to psychological analysis of the study group are described.

2.11 Materials and Methods

2.11.1 Patient Selection

The method for selection of patients, and the prosthetic and surgical aspects of treatment are described in Chapter 4 **(Section 4.7.1)**.

2.11.2 Pre-implant assessment

Initial psychometric assessment was carried out for all ten patients three months after the patients started to wear the optimised conventional dentures.

2.11.3 Post-implant assessment

Two months after the patients started using the mandibular implant-retained overdentures again they all completed psychological questionnaires. This was to allow comparison of psychological profiles before and after implant treatment. Because no change in denture shape had been introduced during implant treatment, it was felt that a two month adaptation period after the addition of implant attachments was sufficient.

2.12 Background of the psychological test used (Appendix 2.2)

The SCL-90-R test has been used widely to assess psychological distress and to assess responses to psychological treatment (Derogatis, 1994). It includes measures of depression, anxiety, interpersonal sensitivity and other psychological symptoms (Primary Symptom Dimensions) and provides a single total score of psychological distress, the Global Severity Index.

The test measures nine primary symptom dimensions and three global indices. The questionnaire consists of 90 items **(Appendix 2.2)**. Patients respond to the questions by describing symptoms over the previous 7 days including the day of completing the questionnaire. Each question is responded to in a scale of five, (i.e., not at all-0, a little bit-1, moderately-2, quite a bit-3, extremely-4). Patients are required to indicate one response for each item and to seek assistance as required, for example, if they have a problem understanding any item.

The Primary Symptom Dimensions of the SCL-90-R were developed through a combination of clinical, rational and empirical analysis procedures and are as follows:

Somatization (SOM): This dimension reflects distress arising from perceptions of bodily dysfunction or pain. For example, Question 56 " *How much were you distressed by feeling weak in parts of your body ?*" is assessing one of the symptom of somatization.

Obsessive-Compulsive (O-C): This is a measure of thoughts, impulses and actions of an irresistible and unwanted nature. For example Question 45, "*How much were you distressed by having to check and double-check what you do ?*" is an assessment of the symptoms of obsessive-compulsive.

Interpersonal-Sensitivity (I-S): This focuses on feelings of inadequacy and inferiority, particularly in comparison with other people. Self-depreciation, self-doubt and marked discomfort during interpersonal interaction are characteristic symptoms in this dimension. People with high scores on I-S report acute self-consciousness and negative expectations in interpersonal behaviour with others and in others' perceptions of them. For example, Question 41 "*How much were you distressed by feeling inferior to others?*" is an assessment of the symptoms of interpersonal sensitivity.

Depression (DEP): The symptoms of this dimension may reflect signs of withdrawal of interest, lack of motivation and loss of vital energy. In addition there may be feelings of hopelessness and thoughts of suicide. For example, Question 29 "*How much were you distressed by feeling lonely ?*" is an assessment of the symptoms of depression.

Anxiety (ANX): The general signs of anxiety include nervousness, tension, apprehension, trembling, panic attacks and feelings of terror. For example Question 57 "*How much were you distressed by feeling tense or keyed up ?*" is an assessment of the symptoms of anxiety.

Hostility (HOS): The hostility dimension reflects thoughts, feelings or actions that are characteristic of the state of anger. For example, Question 11 "*How much were you distressed by feeling easily annoyed or irritated ?*" is an assessment of the symptoms of hostility.

Phobic Anxiety (PHOB): This is defined as a persistent fear response to a specific person, place, object or situation that is irrational and disproportionate to the stimulus and which may lead to avoidance behaviour. For example, Question 50 "*How much were you distressed by having to avoid certain things, places, or activities because they frighten you ?*" is an assessment of the symptoms of phobic anxiety.

Paranoid-Ideation (PAR): This dimension represents a disorder of thinking and the signs of this characteristic are hostility, suspiciousness and grandiosity. For example, Question 18 "*How much were you distressed by feeling that most people cannot be trusted ?*" is an assessment of the symptoms of paranoid-ideation.

Psychoticism (PSY): This consists of items which indicate withdrawn, isolated,

schizoid lifestyle as a first rank symptoms of schizophrenia. For example, Question 85 "*How much were you distressed by the idea that you should be punished for your sins?*" is an assessment of the symptoms of psychoticism.

Additional Items: These are not included under any of the specific primary symptom dimensions, but contribute to the Global Indices as important clinical indicators. For example, Question 89 "*How much were you distressed by feeling of guilt ?*" is an assessment of a symptom in this category.

Global Indices: These are three indices reflecting different aspects of psychological distress. The Global Severity Index (GSI) is an indicator of the current level or depth of psychological disorder, while the Positive Symptom Distress Index (PSDI) functions as a measure of response by indicating whether the respondent was exaggerating or attenuating. It is therefore, a measure of the intensity of any symptoms. The Positive Symptom Total (PST) is a reflection of the number of symptoms endorsed by the respondent, regardless the level of distress reported, therefore it can be interpreted as a measure of symptom breadth.

2.12.1 Scoring the SCL-90-R Test

Scoring the SCL-90-R test is carried out using answering keys and a worksheet manual, or by computerised scoring. In the present study manual scoring was used.

2.12.2 Calculating the Raw scores

The raw scores were calculated be summing the values (i.e., 0-4) of the responses for each item in each of the nine primary symptom dimensions and the additional items. The calculation was carried out with the use of the answer key. The total for each symptom dimension was divided by the number of endorsed items in that dimension to give the raw score.

2.12.3 Calculating the Global Indices

The Global Severity Index (GSI) was obtained by adding together each of the scores of the nine Symptom Dimensions and the Additional Items and dividing this sum by the total number of responses for that particular patient (i.e., 90 if there were no missing

responses). For example, if the total sum of the scores for a patient for the Primary Dimensions and the Additional Items was 13, and there were no missing responses from the total (90), then the raw score for this patient on the GSI would be 0.14. The Positive Symptom Total (PST) was derived by counting the number of items endorsed with a positive (non-zero) response. The Positive Symptom Distress Index (PSDI) was calculated by dividing the summation of each of the nine Primary Symptom Dimensions and the Additional Items by the PST. For example, if the total sum of all Primary Dimensions and the additional Items was 13 and the PST score was 13, then the raw score on the PSDI would be 1.0.

2.12.4 Converting the Raw Scores to Standardised Scores

The standardised/normalised scores (T-scores) were developed to allow comparison between the status of an individual and that of other relevant reference groups, and to enable meaningful comparisons of an individual's status from one domain to another (e.g. relative levels of anxiety and depression) to be made.

The raw scores for the nine symptom dimensions and the three global indices are converted to Standard (Normalised) T-scores, using the norm group appropriate for the subjects being examined. There are four norm groups for the SCL-90-R test: adult psychiatric outpatients (Norm A), adult non-patients (Norm B), adult psychiatric inpatients (Norm C), and adolescent non-patients (Norm E). In this study the norm group for all subjects was adult non-patient (Norm B) females. The development of a gender-specific norm is based on the consistent observation that in UK culture, females have reported significantly more psychological symptoms than males, and they also expressed greater levels of distress associated with emotional conflicts (Derogatis, 1994).

2.13 RESULTS

2.13.1 Symptom Check-List (SCL-90-R)

The SCL-90-R test showed interesting individual data, the significance of which is lost when the data are considered as mean or median values incorporating the whole group. In the description below only the most salient changes will be commented upon.

Patient 1

Prior to implant treatment this patient showed a clinical profile with values mainly below the 50th percentile (9 out of 12). After implant treatment there was a further reduction in five Primary Symptom Dimensions (I-S, DEP, PAR, PSY, GSI), with the only minor increase being associated with PST **(Table 2.10)**. The overall picture is an individual with low SCL-90-R raw scores, which were further reduced following implant treatment **(Fig. 2.1)**

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	0	12	0.0	45
Obsessive-Compulsive	2	10	0.2	49
Interpersonal-Sensitivity.	2	9	0.22	50
Depression	2	13	0.15	45
Anxiety	1	10	0.1	44
Hostility	0	6	0.0	40
Phobic Anxiety	1	7	0.14	54
Paranoid-Ideation.	1	6	0.16	47
Psychoticism	1	10	0.1	53
Additional Items	3	7	0.42	-
Total	**13**	**90**	-	-
Global Severity Index	-	-	0.14	44
Positive Symptom Distress Index	-	-	1.0	37
Positive Symptom Total	-	-	13	37
POST-IMPLANT TREATMENT				
Somatization	0	12	0.0	35
Obsessive-Compulsive	2	10	0.2	49
Interpersonal-Sensitivity.	0	9	0.0	39
Depression	0	13	0.0	34
Anxiety	2	10	0.2	44
Hostility	0	6	0.0	40
Phobic Anxiety	1	7	0.14	54
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	1	7	0.14	-
Total	**6**	**90**	-	-
Global Severity Index	-	-	0.06	37
Positive Symptom Distress Index	-	-	1.0	37
Positive Symptom Total	-	-	6	39

Table 2.10: Patient 1, SCL-90-R T-score before and after implant treatment.

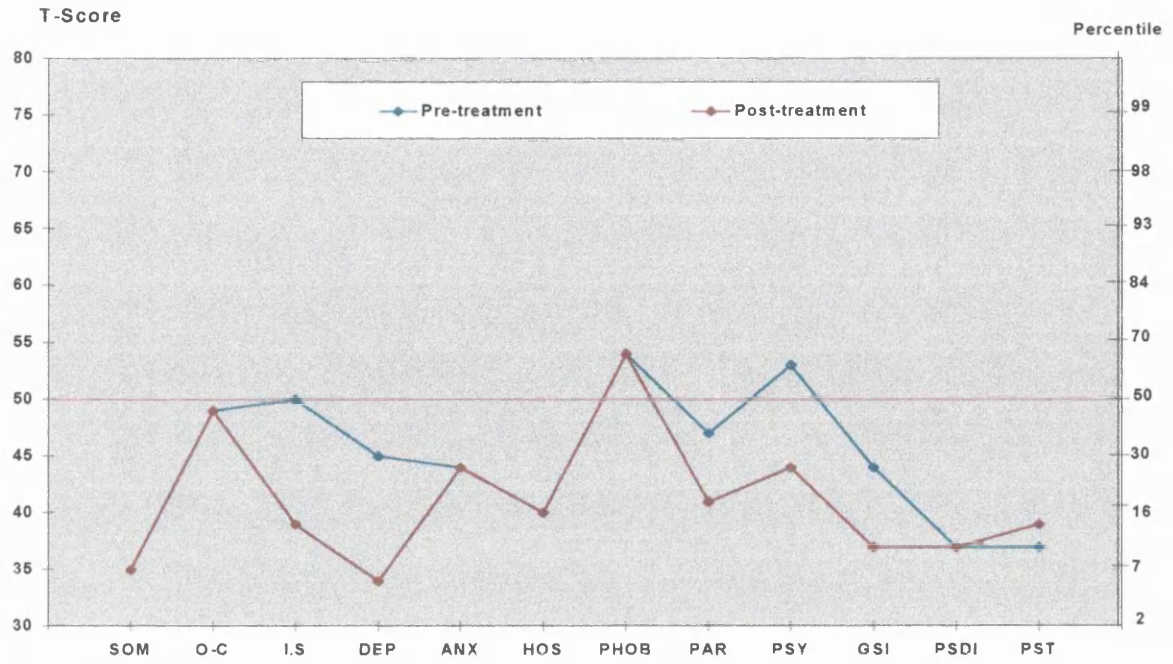

Fig 2.1: Patient 1, SCL-90-R profile before and after implant treatment.

At baseline (pre-treatment) the patient can be seen to have no marked symptoms on any dimension (In fact many dimensions show very low levels of distress). It was noted that scores on depression and psychoticism were further reduced after implant treatment, the reduction in psychoticism implying a reduction in any sense of social isolation.

Patient 2

Prior to implant treatment this patient showed a SCL-90-R profile with values spread to a moderate degree around the 50th percentile. After implant treatment, there were two marked reversals in SCL-90-R scores; a large increase in score value associated with PHOB (lesser increases were associated with SOM, PSY, GSI, PST), and a marked reduction associated with I-S **(Table 2.11)**. After treatment, scores tended to be generally greater than before but, contrary to this general trend, the SCL-90-R score for I-S was greatly reduced following implant treatment **(Fig. 2.2)**.

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	3	12	0.25	49
Obsessive-Compulsive	5	10	0.5	54
Interpersonal-Sensitivity.	4	9	0.44	56
Depression	7	13	0.53	56
Anxiety	5	10	0.5	57
Hostility	0	6	0.0	40
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	1	10	0.1	53
Additional Items	3	7	0.42	-
Total	**28**	**90**	-	--
Global Severity Index	-	-	0.31	52
Positive Symptom Distress Index	-	-	1.21	49
Positive Symptom Total	-	-	23	53
POST-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	11	12	0.91	61
Obsessive-Compulsive	8	10	0.3	50
Interpersonal-Sensitivity.	0	9	0.0	39
Depression	12	13	0.92	61
Anxiety	4	10	0.4	56
Hostility	1	6	0.16	45
Phobic Anxiety	5	7	0.71	65
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	2	10	0.2	59
Additional Items	4	7	0.57	-
Total	**47**	**90**	-	-
Global Severity Index	-	-	0.52	58
Positive Symptom Distress Index	-	-	1.20	49
Positive Symptom Total	-	-	39	60

Table 2.11: Patient 2 SCL-90-R T-score before and after implant treatment.

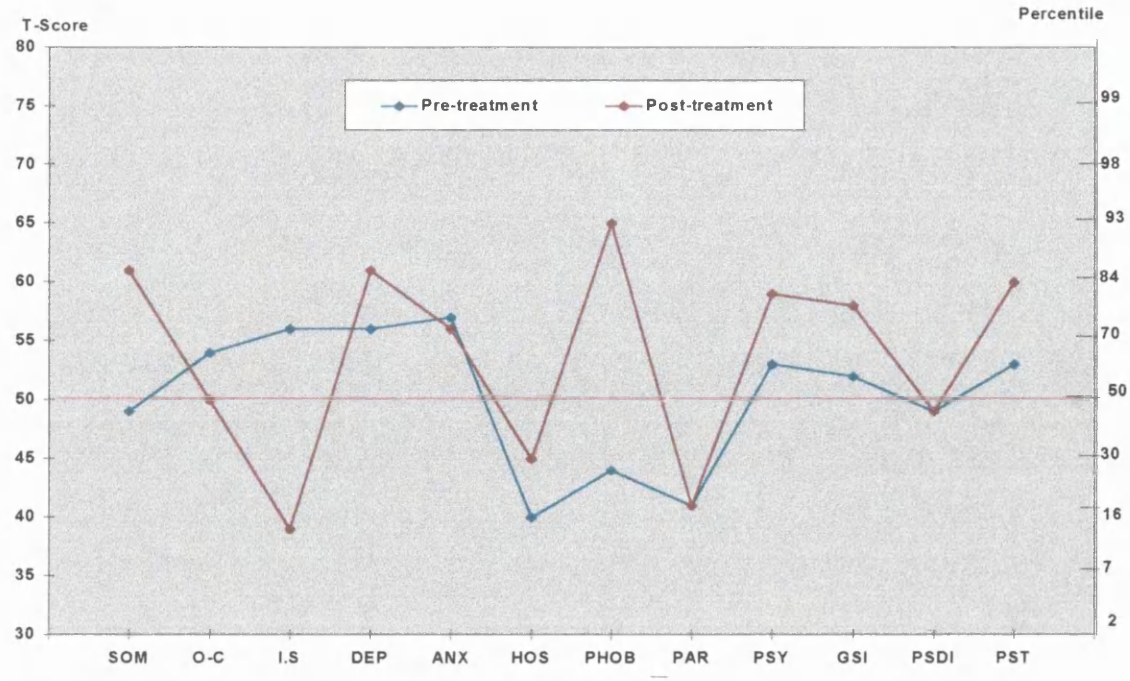

Fig 2.2: patient 2, SCL-90-R profile before and after implant treatment

At baseline this subject was scoring above the norm on several dimensions, particularly inter-personal sensitivity, depression and anxiety. After implant treatment interpersonal-sensitivity improved dramatically, but there was no improvement on depression and anxiety. Interestingly, phobic-anxiety increased markedly following implant treatment. It is unlikely this a reflection of dental treatment but rather is a co-occurring difficulty in the patients' private life.

Patient 3

Prior to implant treatment this patient showed a clinical profile with values mainly above the 50th percentile (11 out of 12). After implant treatment nine of the twelve SCl-90-R values remained similar to the pre-treatment levels, although there was a moderate degree of fluctuation associated with HOS which was increased, and with I-S and PHOB which were reduced **(Table 2.12)**. The overall picture is of an individual with moderately high SCL-90-R raw scores, which were not much changed after implant treatment **(Fig. 2.3)**.

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	5	12	0.41	53
Obsessive-Compulsive	5	10	0.5	54
Interpersonal-Sensitivity.	8	9	0.88	62
Depression	3	13	0.23	48
Anxiety	7	10	0.7	59
Hostility	2	6	0.33	54
Phobic Anxiety	1	7	0.14	54
Paranoid-Ideation.	2	6	0.33	54
Psychoticism	5	10	0.5	64
Additional Items	13	7	1.8	-
Total	**51**	**90**	-	-
Global Severity Index	-	-	0.56	59
Positive Symptom Distress Index	-	-	1.5	56
Positive Symptom Total	-	-	34	58
POST-IMPLANT TREATMENT				
Somatization	3	12	0.25	49
Obsessive-Compulsive	4	10	0.4	54
Interpersonal-Sensitivity.	3	9	0.33	53
Depression	5	13	0.38	52
Anxiety	3	10	0.3	56
Hostility	5	6	0.83	63
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	2	6	0.33	54
Psychoticism	6	10	0.6	65
Additional Items	14	7	2	-
Total	**45**	**90**	-	-
Global Severity Index	-	-	0.5	58
Positive Symptom Distress Index	-	-	1.45	54
Positive Symptom Total	-	-	31	57

Table 2.12: Patient 3 SCL-90-R T-score before and after implant treatment

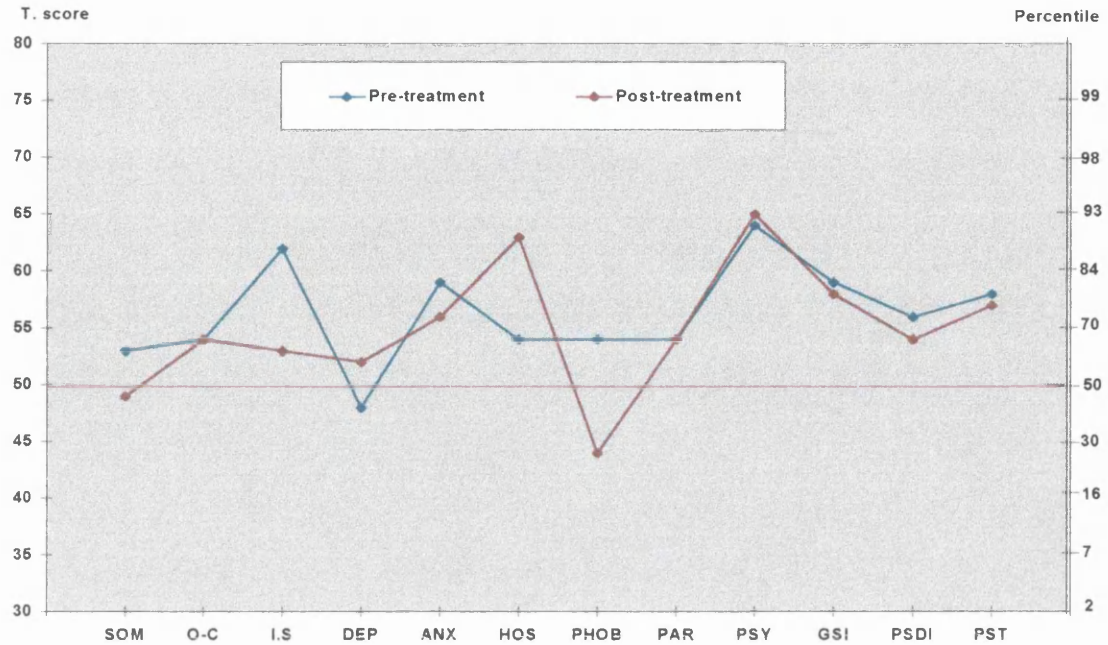

Fig 2.3: Patient 3, SCL-90-R profile before and after implant treatment

At baseline this individual scores highly on interpersonal- sensitivity and psycoticism. After implant treatment there is a moderate increase in hostility dimension and a more marked reduction in phobic-anxiety. Otherwise these states remain much as prior to implant treatment. Again one could not solely ascribe these effects to dental treatment.

Patient 4

Prior to implant treatment this patient showed a clinical profile with SCL-90-R values mainly below the 50th percentile (10 out of 12). After treatment there was little change in the scores. There was a moderate increase in ANX, a slight increase in GSI and PST, and a moderate decrease in PSDI **(Table 2.13)**. The overall picture is of an individual with low SCL-90-R raw scores, with little change following implant treatment **(Fig. 2.4)**.

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	0	12	0.0	35
Obsessive-Compulsive	5	10	0.5	54
Interpersonal-Sensitivity.	0	9	0.0	39
Depression	1	13	0.07	41
Anxiety	0	10	0.0	37
Hostility	1	6	0.16	45
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	4	7	0.57	-
Total	**11**	**90**	-	-
Global Severity Index	-	-	0.12	41
Positive Symptom Distress Index	-	-	1.22	50
Positive Symptom Total	-	-	9	43
POST-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	0	12	0.0	35
Obsessive-Compulsive	4	10	0.4	52
Interpersonal-Sensitivity.	0	9	0.0	39
Depression	1	13	0.07	41
Anxiety	1	10	0.1	44
Hostility	1	6	0.16	45
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	6	7	0.85	-
Total	**13**	**90**	-	-
Global Severity Index	-	-	0.14	44
Positive Symptom Distress Index	-	-	1.08	44
Positive Symptom Total	-	-	12	46

Table 2.13: Patient 4 SCL-90-R T-scores before and after implant treatment

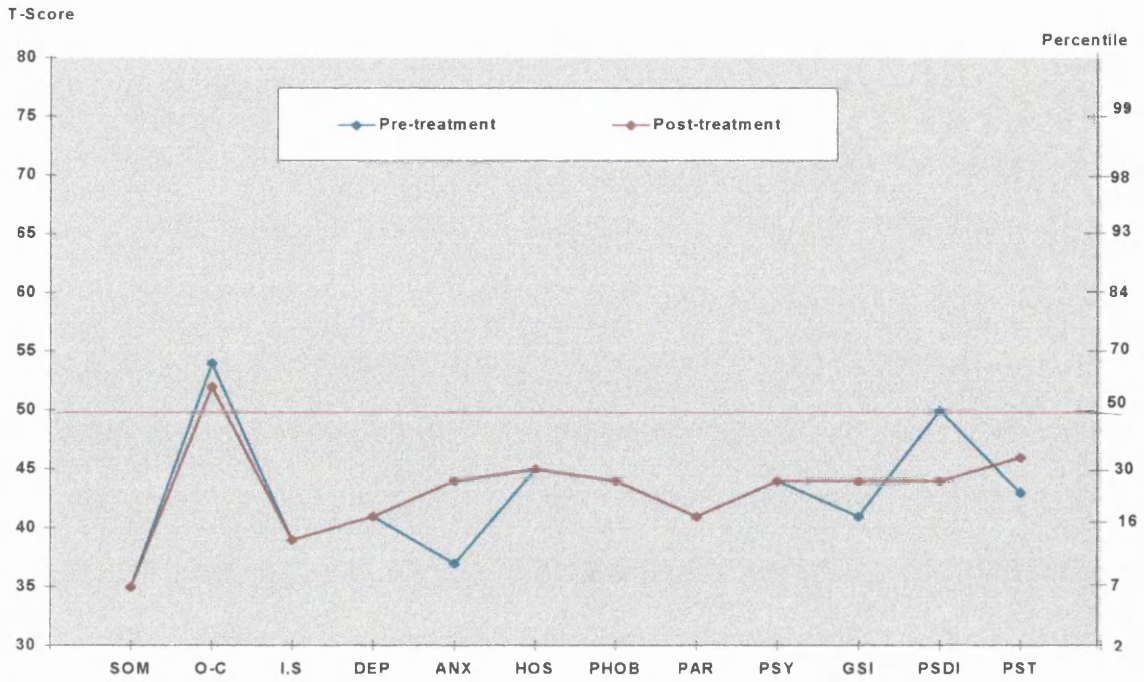

Fig 2.4: Patient 4 SCL-90-R profile before and after implant treatment

It is evident that baseline and post-treatment scores for this subject are both similar and lie below the norm. This subject shows no evidence of distress.

Patient 5

Prior to implant treatment this patient showed a clinical profile with values mainly above the 50th percentile (7 out of 12). After implant treatment seven of the twelve SCL-90-R values remained similar to the pre-treatment levels, although there was a considerable decrease in SOM, moderate decrease in DEP, ANX, PHOB, GSI and PST, and a slight decrease in I-S. A slight increase in score value was associated with O-C and PSDI dimensions **(Table 2.14)**. The overall picture is of an individual with moderately high SCL-90-R raw scores. After treatment scores tended to be generally lesser than before, particularly in the SOM and PHOB dimensions **(Fig.2.5)**

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	4	12	0.33	51
Obsessive-Compulsive	2	10	0.2	49
Interpersonal-Sensitivity.	9	9	1	64
Depression	2	13	0.15	45
Anxiety	7	10	0.7	59
Hostility	1	6	0.16	45
Phobic Anxiety	1	7	0.14	54
Paranoid-Ideation.	5	6	0.83	62
Psychoticism	0	10	0.0	44
Additional Items	5	7	0.71	-
Total	**36**	**90**	-	-
Global Severity Index	-	-	0.4	56
Positive Symptom Distress Index	-	-	1.28	50
Positive Symptom Total	-	-	28	56
POST-IMPLANT TREATMENT				
Somatization	0	12	0.0	35
Obsessive-Compulsive	5	10	0.5	54
Interpersonal-Sensitivity.	7	9	0.77	62
Depression	1	13	0.07	41
Anxiety	4	10	0.4	54
Hostility	1	6	0.16	46
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	6	6	1.0	63
Psychoticism	0	10	0.0	44
Additional Items	4	7	0.57	-
Total	**28**	**90**	-	-
Global Severity Index	-	-	0.31	52
Positive Symptom Distress Index	-	-	1.33	52
Positive Symptom Total	-	-	21	52

Table 2.14: Patient 5 SCL-90-R T-scores before and after implant treatment.

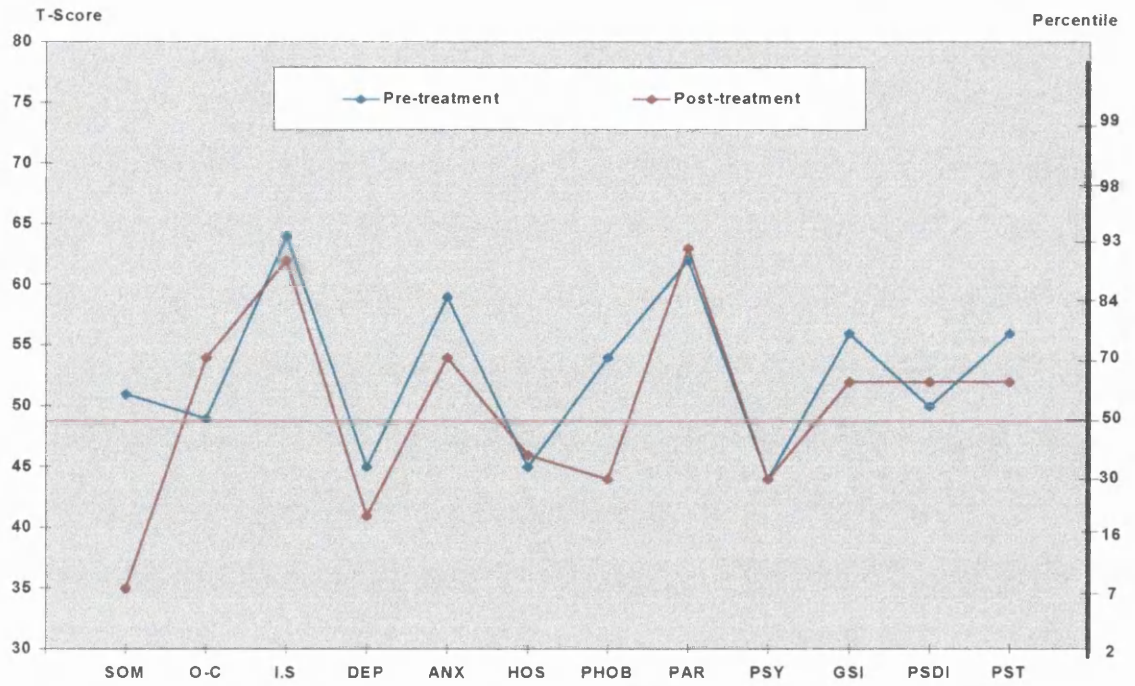

Fig 2.5: Patient 5, SCL-90-R profile before and after implant treatment

In this subject there is little evidence of change from pre-treatment to post-implant treatment with the exception of a large reduction in somatization and moderate change in phobic anxiety. In contrary to Patient 4, this patient shows more marked distress in terms of anxiety, paranoid-ideation and interpersonal-sensitivity. It is difficult to see how provision of dental implant might have any marked effect on these states.

Patient 6

Prior to implant treatment this patient showed a clinical profile with the majority of SCL-90-R values (10 out of 12) below the 50th percentile. After implant treatment there was a remarkable increase in ten out of twelve SCL-90-R values bringing the patient to a moderately high clinical profile. There was considerable increase associated with PARA, I-S, O-C, DEP ANX, HOS, PHOB, PSY, GSI and PST. The only minor decrease was associated with SOM and there was no change in PSDI **(Table 2.15)**. The overall picture is of an individual with showing a considerable change from a low clinical profile to an average profile after implant treatment **(Fig. 2.6).**

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	8	12	0.66	58
Obsessive-Compulsive	0	10	0.0	37
Interpersonal-Sensitivity.	0	9	0.0	39
Depression	2	13	0.15	45
Anxiety	0	10	0.0	37
Hostility	0	6	0.0	40
Phobic Anxiety	0	6	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	0	7	0.0	-
Total	**10**	**89**	-	-
Global Severity Index	-	-	0.11	41
Positive Symptom Distress Index	-	-	1.25	50
Positive Symptom Total	-	-	8	41
POST-IMPLANT TREATMENT				
Somatization	7	12	0.58	57
Obsessive-Compulsive	3	10	0.3	51
Interpersonal-Sensitivity.	4	9	0.44	55
Depression	4	13	0.30	50
Anxiety	1	10	0.1	44
Hostility	1	6	0.16	45
Phobic Anxiety	1	7	0.14	54
Paranoid-Ideation.	5	6	0.83	62
Psychoticism	2	10	0.2	59
Additional Items	2	7	0.28	-
Total	**30**	**90**	-	-
Global Severity Index	-	-	0.33	53
Positive Symptom Distress Index	-	-	1.25	50
Positive Symptom Total	-	-	24	53

Table 2.15: Patient 6, SCL-90-R T-sores before and after implant treatment.

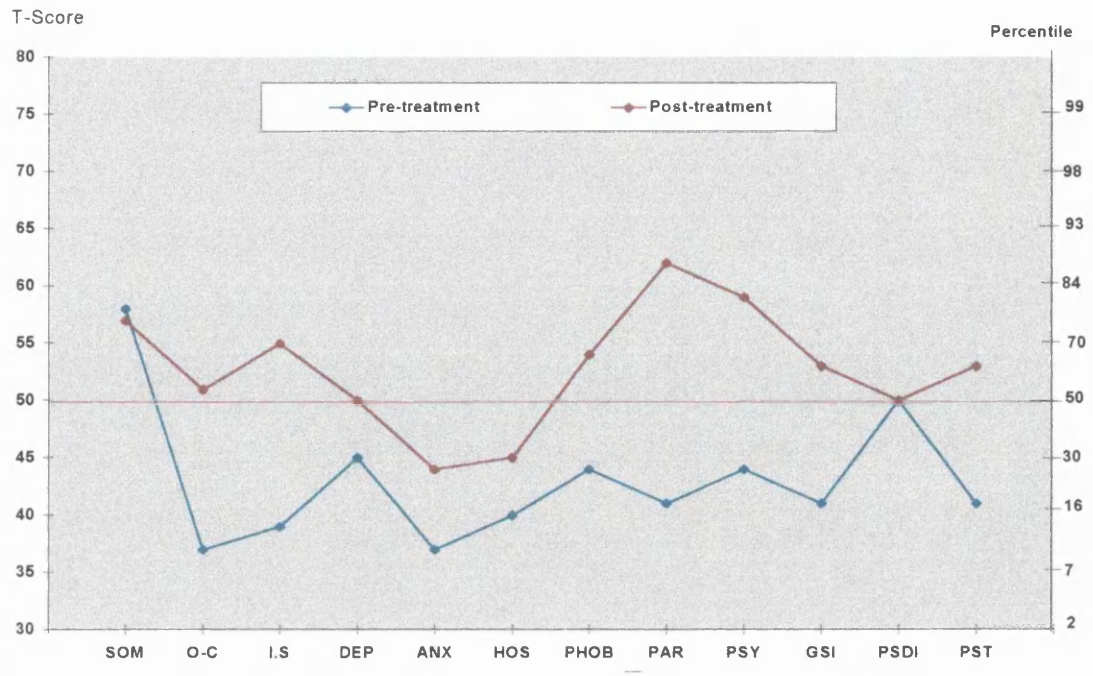

Fig 2.6: Patient 6, SCL-90-R profile before and after implant treatment

It is noteworthy that at baseline this patient showed no evidence of distress other than some elevation in somatization. Following implant treatment scores were elevated on virtually every dimension, and in particular on paranoid-ideation and psychoticism. It is extremely unlikely that so marked a deterioration in state would arise from implant treatment. This patient provides a good illustration of the difficulties encountered with the use of a relatively small sample size and the potential hazards involved when trying to summate the findings in such small experimental group.

Patient 7

Prior to implant treatment this patient showed a SCL-90-R profile with values spread to a moderate degree around the 50th percentile. Following implant treatment there was a moderate increase in score values associated with SOM, O-C, I-S, DEP, ANX, HOS, GSI, PSDI and PST. The score value for PHOB, PAR, PSY remained similar to the pre-treatment levels **(Table 2.16)**. The overall picture is an individual with average SCL-90-R raw scores, with only moderate changes after implant treatment **(Fig.2.7)**.

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	2	12	0.16	44
Obsessive-Compulsive	6	10	0.6	57
Interpersonal-Sensitivity.	1	9	0.11	46
Depression	4	13	0.30	50
Anxiety	0	10	0.0	37
Hostility	2	6	0.33	54
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	3	7	0.42	-
Total	**18**	**90**	-	-
Global Severity Index	-	-	0.2	49
Positive Symptom Distress Index	-	-	1.2	56
Positive Symptom Total	-	-	15	48
POST-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	3	12	0.25	49
Obsessive-Compulsive	10	10	1.0	62
Interpersonal-Sensitivity.	2	9	0.22	50
Depression	5	13	0.38	52
Anxiety	1	10	0.1	44
Hostility	1	6	0.16	45
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	4	7	0.57	-
Total	**26**	**90**	-	-
Global Severity Index	-	-	0.28	50
Positive Symptom Distress Index	-	-	1.2	49
Positive Symptom Total	-	-	21	52

Table 2.16: Patient 7, SCL-90-R T-scores before and after implant treatment

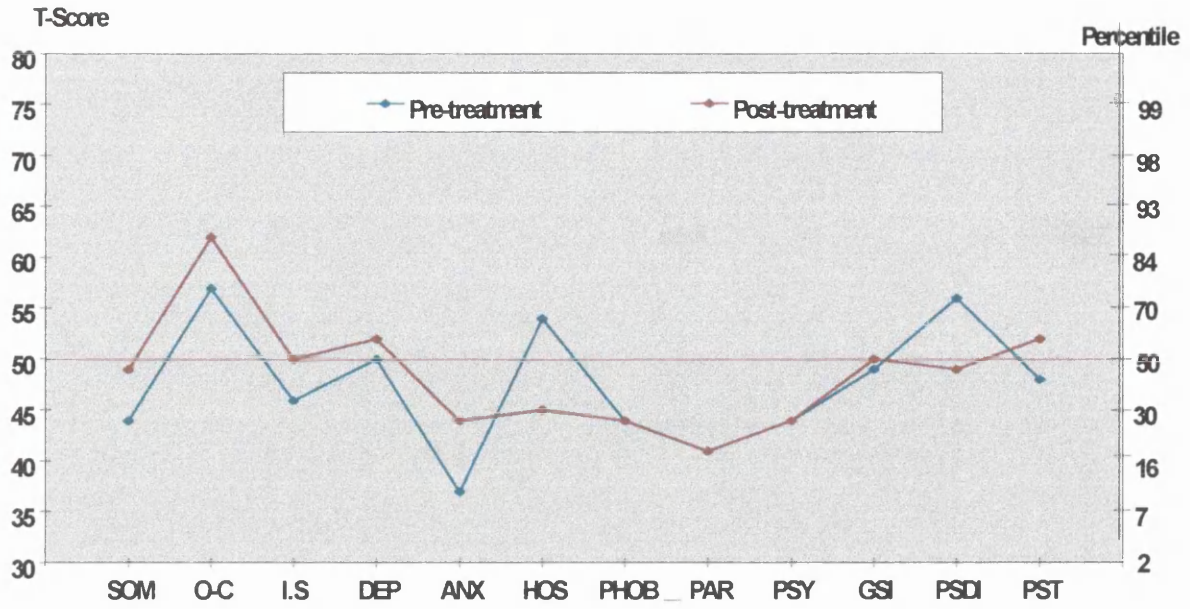

Fig 2.7: Patient 7, SCL-90-R profile before and after implant treatment.

This patient's baseline state shown no real evidence of distress and is maintained post-treatment. This contrasts vividly with the findings for patient 6.

Patient 8

Prior to implant treatment this patient showed a profile with all SCL-90-R values below the 50th percentile. After implant treatment there was little change in the scores, a large increase in score values associated PSDI and ANX, less increases were associated with O-C, GSI, and PST. The rest of the Primary Symptom Dimensions remained similar to the pre-treatment levels **(Table 2.17)**. The overall picture is an individual with low SCL-90-R raw scores, with little changes after implant treatment **(Fig. 2.8)**.

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	2	12	0.16	44
Obsessive-Compulsive	1	10	0.1	44
Interpersonal-Sensitivity.	0	9	0.0	39
Depression	0	13	0.0	34
Anxiety	0	10	0.0	37
Hostility	0	6	0.0	40
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	2	7	0.28	-
Total	**5**	**90**	-	-
Global Severity Index	-	-	0.05	37
Positive Symptom Distress Index	-	-	1.0	37
Positive Symptom Total	-	-	5	38
POST-IMPLANT TREATMENT				
Somatization	2	12	0.16	44
Obsessive-Compulsive	2	10	0.2	49
Interpersonal-Sensitivity.	0	9	0.0	39
Depression	0	13	0.0	34
Anxiety	2	10	0.2	51
Hostility	0	6	0.0	40
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	6	7	0.85	-
Total	**12**	**90**	-	-
Global Severity Index	-	-	0.13	44
Positive Symptom Distress Index	-	-	1.71	59
Positive Symptom Total	-	-	7	40

Table 2.17: Patient 8, SCL-90-R T-scores before and after implant treatment.

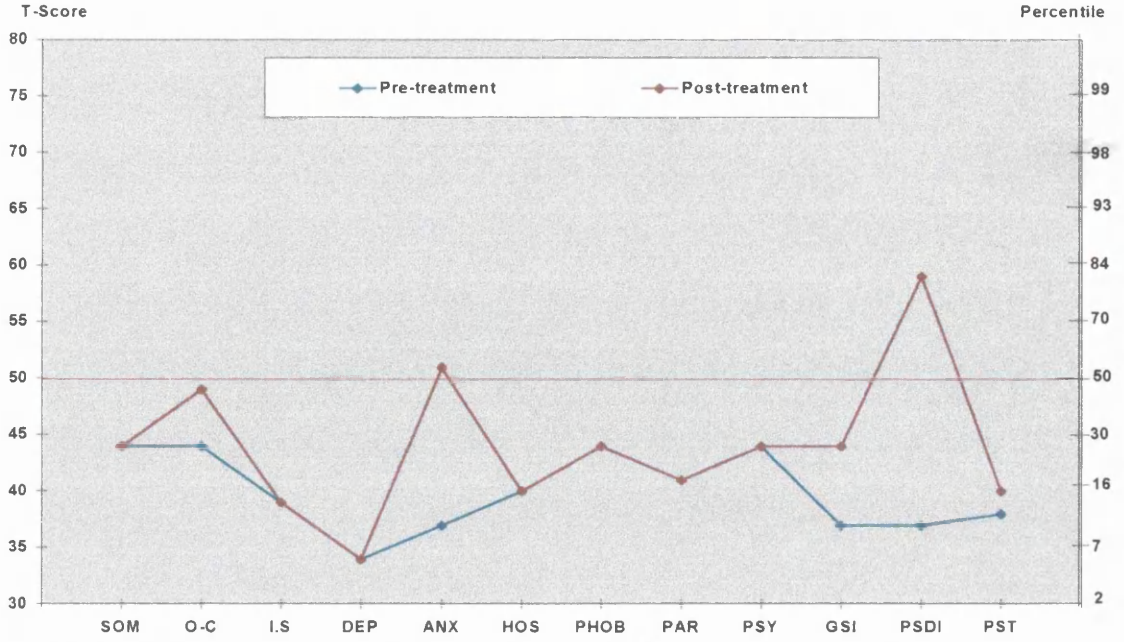

Fig 2.8: Patient 8, SCL-90-R profile before and after implant treatment.

This patient showed no indication of distress on any dimension pre-treatment. This state was sustained with the exception of an increase in anxiety and marked change on the positive symptom distress index. Again it is noteworthy that these changes occurred despite apparently successful implant treatment.

Patient 9

Prior to implant treatment this patient showed a clinical profile with values mainly below the 50th percentile (11 out of 12). After implant treatment there were two marked reversals in SCL-90-R scores; a moderate increase in score value associated with O-C and a marked reduction associated with PHOB. The rest of the Primary Symptom Dimensions remained similar to the pre-treatment levels **(Table 2.18)**. The overall picture is an individual with low SCL-90-R scores, which were not much changed following implant treatment **(Fig. 2.9)**.

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	3	12	0.25	49
Obsessive-Compulsive	0	10	0.0	37
Interpersonal-Sensitivity.	1	9	0.1	46
Depression	2	13	0.15	45
Anxiety	0	10	0.0	37
Hostility	0	6	0.0	40
Phobic Anxiety	1	7	0.14	54
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	1	7	0.14	-
Total	**8**	**90**	-	-
Global Severity Index	-	-	0.08	37
Positive Symptom Distress Index	-	-	1	37
Positive Symptom Total	-	-	8	41
POST-IMPLANT TREATMENT				
Somatization	3	12	0.25	49
Obsessive-Compulsive	1	10	0.1	44
Interpersonal-Sensitivity.	1	9	0.11	46
Depression	2	13	0.15	45
Anxiety	0	10	0.0	37
Hostility	0	6	0.0	40
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	1	7	0.14	-
Total	**8**	**90**	-	-
Global Severity Index	-	-	0.08	37
Positive Symptom Distress Index	-	-	1	37
Positive Symptom Total	-	-	8	41

Table 2.18: Patient 9, SCL-90-R T-scores before and after implant treatment.

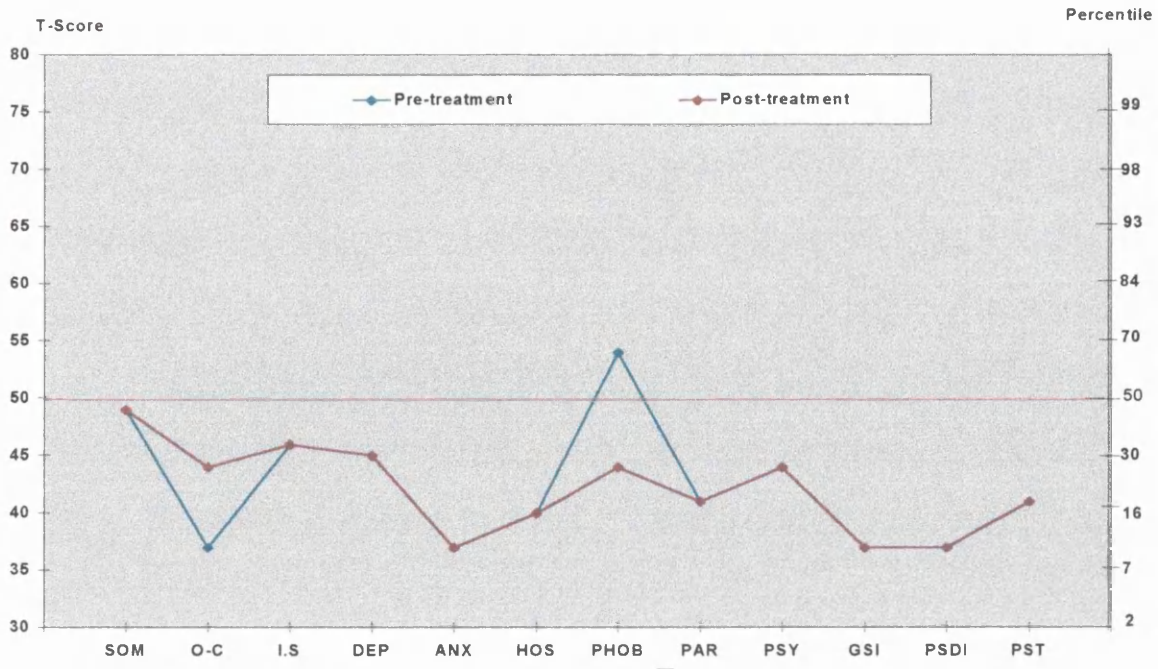

Fig 2.9: Patient 9, SCL-90-R profile before and after implant treatment.

This patient showed remarkable stability over time, and one can note reduction in phobic-anxiety after implant treatment.

Patient 10

Prior to implant treatment this patient showed a clinical profile with SCL-90-R values mainly below the 50th percentile (8 out of 12). Following implant treatment there was moderate increase in score associated with DEP and lesser increases were associated with SOM, O-C and PSDI. On the other hand, moderate reductions were associated with I-S and PAR, with a minor decrease being associated with PST **(Table 6.19)**. The overall picture is of an individual with low SCL-90-R scores, with little change after implant treatment **(Fig. 2.10)**.

PRE-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	1	12	0.08	39
Obsessive-Compulsive	4	10	0.4	52
Interpersonal-Sensitivity.	2	9	0.22	50
Depression	0	13	0.0	34
Anxiety	0	10	0.0	37
Hostility	0	6	0.0	40
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	2	6	0.33	54
Psychoticism	0	10	0.0	44
Additional Items	2	7	0.28	-
Total	**11**	**90**	-	-
Global Severity Index	-	-	0.12	41
Positive Symptom Distress Index	-	-	1.22	50
Positive Symptom Total	-	-	9	43
POST-IMPLANT TREATMENT				
Primary Symptom Dimension	**Sum/Item Response**	**#/Response**	**Raw-score**	**T-Score**
Somatization	2	12	0.16	44
Obsessive-Compulsive	5	10	0.5	54
Interpersonal-Sensitivity.	0	9	0.0	39
Depression	3	13	0.23	48
Anxiety	0	10	0.0	37
Hostility	0	6	0.0	40
Phobic Anxiety	0	7	0.0	44
Paranoid-Ideation.	0	6	0.0	41
Psychoticism	0	10	0.0	44
Additional Items	1	7	0.14	-
Total	**11**	**90**	-	-
Global Severity Index	-	-	0.12	41
Positive Symptom Distress Index	-	-	1.37	53
Positive Symptom Total	-	-	8	41

Table 2.19: Patient 10, SCL-90-R T-scores before and after implant treatment.

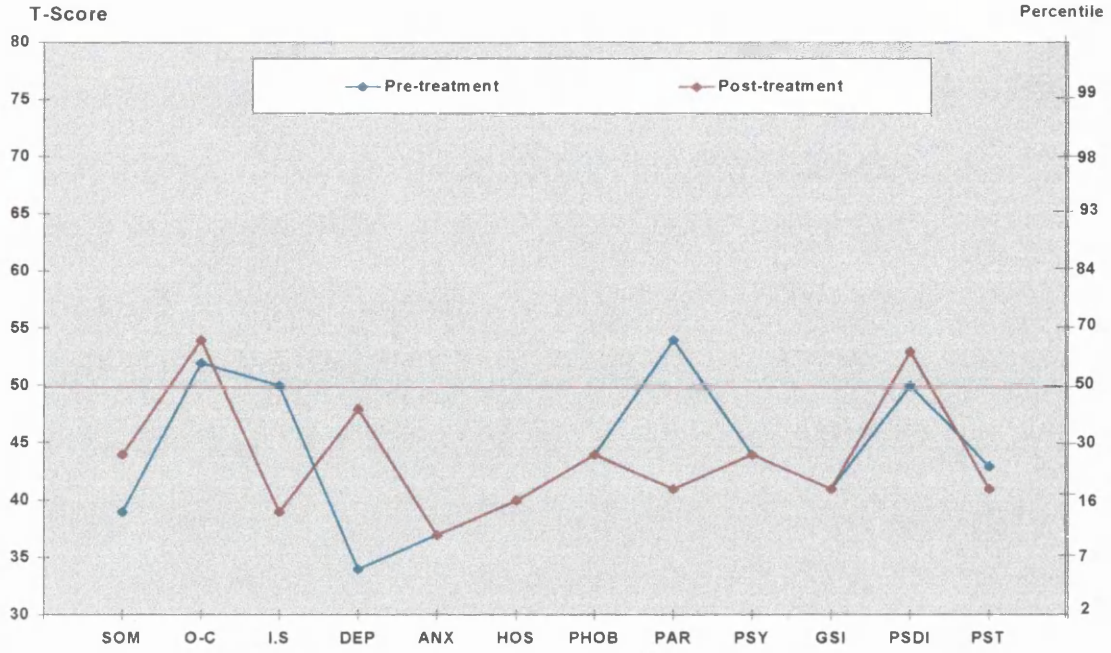

Fig 2.10: Patient 10, SCL-90-R profile before and after implant treatment.

This patients' scores both pre and post implant treatment indicated lack of distress.

2.14 DISCUSSION

In the second psychological study there was considerable inter-patient variation in initial psychological status, the effect of this variation being accentuated by the small sample size. Following implant treatment there were often marked changes, indicative of both improvements and deterioration in mental status. While it is tempting to ascribe improvements in mental condition to dental treatment, this cannot be justified as one would have reconciled the deterioration in state of some subject with apparently successful treatment.

The likely explanation is that change in underlying psychological status is more likely to be due to other life events than to dental treatment. This study highlights that it is imperative to consider objective clinical measures of treatment outcome and feedback questionnaires when assessing clinical success.

2.15 CONCLUSION

Owing to the lack of an apparent change in patients' psychological status after implant treatment, a further investigation of the features identified in this study with a larger sample size, perhaps using an appropriate psychological tests, might still show that this approach to outcome measurement has something to offer to the dental clinician.

CHAPTER THREE

PATIENT SELF-ASSESSMENT WITH THE USE OF DENTAL FUNCTION QUESTIONNAIRES.

3.1 INTRODUCTION

Many variables have been found to influence patients' acceptance of complete dentures. These include factors such as denture quality, patient attitude to dentures, patient personality, the patient/dentist relationship, the condition of the oral tissues, previous denture experience and demographic variables (Van Wass, 1990b; Berg, 1993).

In this context it is apparent from the prosthetic literature that two main methods have been used to assess and evaluate the function of dental prostheses. The first approach has featured the use of objective measurement to assess masticatory functions such as chewing and eating ability, bite force generation and speech articulation, and these assessments have often been carried out with the use of specially designed apparatus. The second approach has been to evaluate patient perception of complete denture treatment, for example by self-assessment, allowing the patients to record their views of oral function in structured questionnaires.

Patient satisfaction with complete dentures retained by implants has also been evaluated by subjective and objective methods. For example, satisfaction with mandibular implant-retained overdentures, supported by ITI® dental implants was assessed by Wismeijer et al (1992) in 64 edentulous patients who were questioned on their experiences with treatment up to 6 year after implant placement. It was reported that an extremely high proportion (95%) were satisfied with their new prostheses with respect to function, comfort and social rehabilitation. In a multicentre study, Boerrigter et al (1995) carried out a comparative investigation using self-assessment questionnaires in two groups of 150 patients who had mandibular denture problems of long standing. Patients in the first group were treated with mandibular overdentures retained by two implant fixtures, opposed by optimised maxillary complete dentures. Patients in the second group were provided with new optimised complete dentures in both jaws, as a control. It was reported that patients treated with implant-retained overdentures

appeared to be more satisfied than the control group and this was reflected in overall satisfaction and with denture function, aesthetics, comfort and speech. While it was reported that in general terms more than half of the control group was satisfied with the new conventional dentures, when specific questions on particular problems were asked, it appeared that only a small number of patients were satisfied with the conventional mandibular dentures.

3.2 SELF-ASSESSMENT PROCEDURE

In the present self-assessment investigation, ten female subjects (over the age of 55 years) with problems of mandibular denture instability were screened to evaluate their oral status and were accepted for implant treatment. Prior to implant placement, all patients were provided with conventional complete dentures designed with full base extension, adequate inter-occlusal clearance and with the jaw relationship recorded with the mandible in the retruded position. Care was taken to ensure that tooth position was in balance with the surrounding musculature. The teeth were set in balanced articulation on a semi-adjustable articulator. After delivery of the dentures, the patients were kept under close review for one month, final adjustment to the occlusion and the impression surfaces of the dentures being carried out as required. All ten patients wore these optimised conventional dentures for a three months period before implant treatment commenced.

Subjective evaluation of the patients' experience with previous dentures and the optimised conventional dentures was carried out with the use of self-administered questionnaires. These dental function questionnaires were designed specifically for the purpose of this study.

In the first questionnaire the patient's experience with dentures constructed prior to attending Glasgow Dental Hospital and with the optimised conventional dentures was assessed, with particular attention given to the function of the mandibular denture **(Appendix 3.1)**. The first section of this questionnaire contained general items referring to socio-economic and health status, and specific dental topics such as the length of time of edentulism, number of previous dentures, and the length of time of wearing dentures. In the second part of this questionnaire the patients' views on comfort, quality of speech,

level of aesthetics and denture stability, particularly during masticatory function, were sought along with their observations on the effects of their dentures on social interaction. This section compared the performance of the original dentures that the patients had been wearing on presentation to Glasgow Dental Hospital with that of the replacement conventional dentures, of optimised design, made at Glasgow Dental Hospital. This initial assessment was carried out three months after the provision of the optimised conventional dentures.

Following implant placement and two months after the mandibular implant-retained overdentures had been in function, patients were again asked to express their opinions with respect to masticatory function, using a second questionnaire in which comparison was made between the optimised conventional dentures and the implant-retained mandibular overdentures. In addition, in the second self-assessment questionnaire there were questions dealing with patients' experience with the surgical procedures of implant placement **(Appendix 3.2)**.

3.3 RESULTS:
Previous Dentures compared with Replacement Dentures of Optimised Design.

3.3.1 Denture wearing practises
(*Appendix 3.1, questions 10&11 / **Appendix 3.2, questions 1&2)

There was little apparent change in the pattern of denture wearing brought about by the construction conventional dentures of optimised design. It appears that one subject who initially left the maxillary denture out at night, started to wear it at all times **(Table 3.1).**

Q: **Do you wear your upper and lower dentures?**				
	PCD*		**OCD****	
	Lower	**Upper**	**Lower**	**Upper**
a) All the time	**5**	**7**	**5**	**8**
b) Sometimes	**1**	**1**	**1**	**1**
c) Never	**1**	**0**	**1**	**0**
d) All times other than sleeping	**3**	**2**	**3**	**1**

Table 3.1: Patients' responses for wearing previous and optimised dentures.
***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.2 Problems with conventional dentures
(*Appendix 3.1, question 12 / **Appendix 3.2, question 3)

There was a small reduction in the problems encountered with conventional dentures after the provision of optimised dentures, although nine of the ten patients still had significant problems with their mandibular denture **(Table 3.2).**

Q: **Do you have problems/troubles with your lower and upper dentures?**				
	PCD*		**OCD****	
	Lower	**Upper**	**Lower**	**Upper**
a) Significant problems	**10**	**3**	**9**	**1**
b) Minor problems	**0**	**0**	**1**	**0**
c) No problems	**0**	**7**	**0**	**9**

Table 3.2: Patients' responses for wearing previous and optimised dentures.
***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.3 Comfort with conventional dentures
(*Appendix 3.1, question 13 / **Appendix 3.2, question 4)

A distinct increase in patient comfort was evident after three months of wearing the optimised complete dentures. Eight subjects reported that their optimised dentures were comfortable or very comfortable, only one patient was uncomfortable with the optimised denture **(Table 3.3)**.

Q: **Would you describe your previous dentures as being?**		
	PCD*	**OCD****
a) Very comfortable	**1**	**5**
b) Comfortable	**2**	**3**
c) Neither comfortable nor uncomfortable	**2**	**1**
d) Rather uncomfortable	**2**	**0**
e) Very uncomfortable	**3**	**1**

Table 3.3: Patients' responses for comfort with previous and optimised dentures.
***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.4 Pain with conventional dentures
(*Appendix 3.1, question 22 / **Appendix 3.2, question 13)

There was an apparent change in the occurrence of pain after patients had been provided with the optimised dentures; four patients reported that their new dentures never caused pain. Nonetheless, five patients still had pain occurring on occasional or frequent basis and one patient reported that the optimised dentures always caused pain **(Table 3.4).**

Q: **Which statement best describes your previous dentures?**		
	PCD*	**OCD****
a) They never caused pain	**0**	**4**
b) Occasionally caused pain	**4**	**1**
c) Frequently caused pain	**4**	**4**
d) Always caused pain	**2**	**1**

Table 3.4: Patients' responses for pain with previous and optimised dentures.
***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.5 Eating with conventional dentures
(*Appendix 3.1, question 16 / **Appendix 3.2, question 7)

There was an apparent change in the patients' concern about denture instability when eating; four of the ten patients became completely unconcerned after being provided with optimised complete dentures. Nevertheless, four patients were still very concerned about eating with the optimised dentures **(Table 3.5)**.

Q: **How concerned were you that your previous dentures might slip or fall out when you were eating?**		
	PCD*	**OCD****
a) Could not have been more concerned	**2**	**1**
b) Very concerned	**3**	**3**
c) Mildly concerned	**4**	**1**
d) Moderately unconcerned	**1**	**1**
e) Completely unconcerned	**0**	**4**

Table 3.5: Patients' responses for eating with previous and optimised dentures. ***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.6 Speaking with conventional dentures
(*Appendix 3.1, question 17 / **Appendix 3.2, question 8)
(*Appendix 3.1, question 18 / **Appendix 3.2, question 9)

A small reduction in speech difficulty was found with the optimised dentures, although five patients were still very concerned when speaking with the optimised dentures **(Table 3.6a)** and six patients still had some speech problems **(Table 3.6b).**

Q: **How concerned were you that your previous dentures might slip or fall out when you were speaking?**		
	PCD*	**OCD****
a) Could not have been more concerned	**3**	**3**
b) Very concerned	**4**	**2**
c) Mildly concerned	**1**	**2**
d) Moderately unconcerned	**1**	**1**
e) Completely unconcerned	**1**	**2**

Table 3.6a: Patients' responses for speaking with previous and optimised dentures. ***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

Q: **Thinking about your previous dentures?**		
	PCD*	**OCD****
a) They did not affect my speech	**0**	**2**
b) Occasionally made speaking difficult	**2**	**2**
c) Frequently caused difficulty with speech	**3**	**4**
d) Always caused difficulty with speech	**5**	**2**
e) They had to be removed to speak	**0**	**0**

Table 3.6b: Patients' responses for speaking with previous and optimised dentures. ***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.7 Denture awareness
(*Appendix 3.1, question 14 / **Appendix 3.2, question 5)

There was a clear reduction in the patients' general awareness of wearing dentures. While only one patient originally indicated being aware of complete dentures only occasionally, seven patients were aware of the optimised dentures only occasionally or very rarely **(Table 3.7).**

Q: **Were you aware of your previous dentures in your mouth?**		
	PCD*	**OCD****
a) Very rarely	**0**	**4**
b) Occasionally	**1**	**3**
c) Moderately often	**2**	**1**
d) Most of the time	**4**	**1**
e) All of the time	**3**	**1**

Table 3.7: Patients' responses for awareness with previous and optimised dentures. ***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.8 Self confidence with conventional dentures
(*Appendix 3.1, question 21 / **Appendix 3.2, question 12)

While an improvement in self-confidence was apparent, this was only a weak trend. Even with optimised conventional dentures there was a clear lack of confidence associated with denture wearing **(Table 3.8).**

Q: **How did your previous denture affect your self confidence?**		
	PCD*	**OCD****
a) Very bad effect	**1**	**0**
b) Bad effect	**7**	**6**
c) No effect	**2**	**2**
d) Good effect	**0**	**1**
e) Very good effect	**0**	**1**

Table 3.8: Responses for self-confidence with previous and optimised dentures. ***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.9 Chewing ability with conventional dentures (*Appendix 3.1, question 15 / **Appendix 3.2, question 6)

The patients considered that there was a moderate improvement in masticatory function after provision of the optimised dentures, with seven patients apparently having an acceptable level of function, whereas only three patients considered they could "chew well" or only had occasional difficulty with their original dentures **(Table 3.9).**

Q: **Thinking about your previous dentures, did you?**		
	PCD*	**OCD****
a) Chew well with them	**1**	**5**
b) Have occasional difficulty chewing	**2**	**2**
c) Have frequent difficulty chewing	**2**	**1**
d) Always have difficulty chewing	**4**	**1**
e) Remove them to chew food	**1**	**1**

Table 3.9: Patients' responses for chewing with previous and optimised dentures. ***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.10 Patients' appearance with complete dentures (*Appendix 3.1, question 23 / **Appendix 3.2, question 14)

There was a considerable change in the patients' opinion of appearance following the provision of the optimised dentures. Four patients considered there was a significant improvement and another four reported some improvement, after three months of wearing the optimised dentures **(Table 3.10).**

Q: **Thinking about your previous dentures, do you think they made?**		
	PCD*	**OCD****
a) A significant improvement to your appearance	**0**	**4**
b) Some improvement in your appearance	**2**	**4**
c) No difference in your appearance	**5**	**2**
d) Your appearance worse	**3**	**0**

Table 3.10: Patients' responses for appearance with previous and optimised dentures. ***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.11 Social interaction with conventional dentures (*Appendix 3.1, question 19 / **Appendix 3.2, question 10)

There was little apparent change in social activity. Only two patients appeared to let their denture problems interfere with social activity and acceptance of meal invitations, but it is unlikely that social activity would change in a short period of three months, as a number of other related factors are of importance **(Table 3.11).**

Q: **Thinking about your previous denture, did you refuse invitations to go for meals or to social functions?**		
	PCD*	**OCD****
a) Never	**6**	**6**
b) Very rarely	**1**	**0**
c) Occasionally	**1**	**2**
d) Most of the time	**2**	**2**
e) On every occasion	**0**	**0**

Table 3.11: Responses for social interaction with previous and optimised dentures. ***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.3.12 Patients' perception of conventional complete dentures (*Appendix 3.1, question 20 / **Appendix 3.2, question 11)

There was an apparent change in the patients' perception of their dentures; whereas all ten patients felt that their original dentures felt like a foreign body, this view was held by only four patients when optimised dentures were provided **(Table 3.12).**

Q: **Which statement most closely applies to how your previous dentures felt in your mouth ?**		
	PCD*	**OCD****
a) Always like a foreign body	**3**	**1**
b) Usually like a foreign body	**7**	**3**
c) Usually like part of yourself	**0**	**6**
d) Always like part of yourself	**0**	**0**

Table 3.12: Patients' responses for perception with previous and optimised dentures. ***PCD**, Previous complete denture. ****OCD**, Optimised complete denture.

3.4 RESULTS:
Dentures of Optimised Design compared with Implant Retained-Dentures.

Three months after the optimised dentures had been in function, implant surgery was carried out and, after an appropriate interval for osseointegration, the mandibular denture was modified to link with the implant fixtures. Two months after the mandibular implant-retained overdentures had been in function, the patients were requested to complete the second dental function questionnaire, in order to allow a comparison between experience with the optimised complete dentures and the mandibular implant-retained overdentures. It is emphasised that the optimised conventional dentures were converted after implant fixtures placement by the addition of two attachments to engage the implants, and there were no other modifications. Thus, this questionnaire particularly examines the effect of increased lower denture stability following implant treatment.

3.4.1 Influence of the implant-retained overdenture on patients' lives (*Appendix 3.1, question 24 / **Appendix 3.2, question 15)

There was a remarkable change in patients' lives brought about by being provided with the implant-retained overdenture; six of the ten subjects reported a significant difference in their lives and the other four reported that their implant-retained overdentures had transformed their lives completely, even as compared to their experience with the optimised dentures **(Table 3.13).**

Q: **Has the new* (optimised)/implant-retained** denture?**		
	OCD*	**OVD****
a) Made no difference to your life	**0**	**0**
b) Made little difference	**3**	**0**
c) Made a moderate difference	**1**	**0**
d) Made a significant difference	**5**	**6**
e) Transformed your life	**0**	**4**

Table 3.13: Influence of optimised denture and implant-retained overdenture.
***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.2 Problems with implant-retained overdenture (*Appendix 3.1, question 35 / **Appendix 3.2, question 28)

There was a distinct reduction in denture problems occurring after patients had been provided with optimised complete dentures. Although only three subjects had a small number of problems with the optimised denture, all ten patients reported a dramatic reduction in denture problems after being provided with an implant-retained overdenture **(Table 3.14)**.

Q: Does your new* (optimised)/implant-retained** denture cause you?		
	OCD*	**OVD****
a) No problems	**5**	**9**
b) Some small problems	**2**	**1**
c) A number of problems	**3**	**0**
d) A great many problems	**0**	**0**

Table 3.14: Problems with optimised denture and implant-retained overdenture. ***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.3 Comfort with implant-retained overdenture (*Appendix 3.2, question 4 / **Appendix 3.2, question 27)

A distinct increase in patient comfort was evident, after three months of wearing the optimised dentures. Eight of the ten subjects reported that their optimised dentures were generally comfortable. Following implant treatment, all patients indicated they were comfortable or very comfortable **(Table 3.15)**.

Q: Would you describe your new* (optimised)/implant-retained** denture as being ?		
	OCD*	**OVD****
a) Very comfortable	**5**	**9**
b) Comfortable	**3**	**1**
c) Neither comfortable nor uncomfortable	**1**	**0**
d) Rather uncomfortable	**0**	**0**
e) Very uncomfortable	**1**	**0**

Table 3.15: Comfort with optimised denture and implant-retained overdenture. ***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture

3.4.4 Pain with implant-retained overdenture (*Appendix 3.2, question 13 / **Appendix 3.2, question 26)

There was an apparent change in the occurrence of pain after patients were provided with the new optimised denture; four patients reported that their new optimised dentures never caused pain. Nonetheless, five of the ten patients still had pain occurring on an occasional or frequent basis, and one patient reported that the optimised conventional denture always caused pain. Following implant treatment no patient experienced any pain with the implant-retained overdenture **(Table 3.16)**.

Q: **Which statement best describes your previous* (optimised) / implant-retained** denture?**	**OCD***	**OVD****
a) They never caused pain	**4**	**10**
b) Occasionally caused pain	**1**	**0**
c) Frequently caused pain	**4**	**0**
d) Always caused pain	**1**	**0**

Table 3.16: Pain with optimised denture and implant-retained overdenture.
***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.5 Self-consciousness with implant-retained overdenture (*Appendix 3.1, question 36 / **Appendix 3.2, question 29)

There appeared to be a considerable reduction in self-consciousness brought about by implant treatment, with only two patients reporting minor concerns after they had been provided with the implant-retained overdenture **(Table 3.17)**.

Q: **How self-conscious are you about your new* (optimised) / implant-retained** denture?**	**OCD***	**OVD****
a) Not at all	**5**	**8**
b) A little bit	**3**	**2**
c) Quite a lot	**1**	**0**
d) A very great deal	**1**	**0**

Table 3.17: Self-consciousness with optimised and implant-retained overdenture.
* **OCD** Optimised complete denture.****OVD**, Implant-retained overdenture.

3.4.6 Denture stability with implant-retained overdenture (*Appendix 3.1, question 27 / **Appendix 3.2, question 18)

There was a remarkable improvement in denture stability provided by the optimised conventional denture, as eight patients reported a significant improvement in comparison with their original conventional denture. However, following implant treatment all ten patients indicated a significant improvement in their denture stability even in comparison with the optimised conventional denture **(Table 3.18)**.

Q: **In comparison with your previous denture, do you feel that the new (optimised)*/implant-retained** denture fits?**	**OCD***	**OVD****
a) Significantly less well	**0**	**0**
b) A little less well	**1**	**0**
c) Of equal stability	**0**	**0**
d) A little better	**1**	**0**
e) Significantly better	**8**	**10**

Table 3.18: Denture stability with optimised denture and implant-retained overdenture. ***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.7 Self-confidence with implant-retained overdenture (*Appendix 3.1, question 33 / **Appendix 3.2, question 24)

It is apparent there was a considerable change in self-confidence after the patients were provided with the implant-retained overdentures; eight patients reported they felt much more confident. Only one patient reported this level of confidence after three months of wearing the optimised conventional denture **(Table 3.19)**.

Q: **Has the new (optimised)*/implant-retained** denture made you feel?**	**OCD***	**OVD****
a) Much less confident	**0**	**0**
b) A little less confident	**0**	**0**
c) Has not affected my confidence	**6**	**0**
d) A little more confident	**3**	**2**
e) Much more confident	**1**	**8**

Table 3.19: Self-confidence with optimised denture and implant-retained overdenture. ***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture

3.4.8 Psychological security with implant-retained overdenture (*Appendix 3.1, question 26 / **Appendix 3.2, question 17)

While most patients indicated achieving a high level of psychological security after being provided with the optimised conventional denture, the implant-retained overdentures were graded as highly as was possible with respect to this factor **(Table 3.20)**.

Q: **With your new*(optimised) / implant-retained** denture in place, do you feel?**	**OCD***	**OVD****
a) More secure than previously	**7**	**10**
b) No more or less secure than previously	**2**	**0**
c) Less secure than previously	**1**	**0**

Table 3.20: Psychological security with optimised and implant-retained overdenture. ***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.9 Eating ability with implant-retained overdenture (*Appendix 3.1, question 28 / **Appendix 3.2, question 19)

While there was a significant improvement in the patients' eating ability after three months of wearing the optimised complete dentures. After the provision of the implant-overdenture each of the ten patients reported much improved function in comparison even with the optimised conventional denture **(Table 3.21)**.

Q: **In comparison with your previous denture, do you feel that with the new*(optimised)/implant-retained** denture, you can eat?**	**OCD***	**OVD****
a) Much less well than you could before	**1**	**0**
b) A little less well than before	**0**	**0**
c) Much the same as you could before	**1**	**0**
d) A little better than you could before	**1**	**0**
e) Much better than you could before	**7**	**10**

Table 3.21: Eating ability with optimised denture and implant-retained overdenture. ***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.10 Diet with implant-retained overdenture (*Appendix 3.1, question 29 / **Appendix 3.2, question 20)

While there was a considerable improvement in what patients felt they could cope with in terms of masticatory function, brought about by the construction of optimised conventional dentures, following implant treatment there was a further marked improvement in the patients' ability to eat without restriction **(Table 3.22)**.

Q: When wearing the new* (optimised) / implant-retained** denture		
	OCD*	OVD**
a) You can eat what you like	0	6
b) You can eat most things	7	4
c) Your diet is quite restricted	2	0
d) Your diet is very restricted	1	0

Table 3.22: Diet restriction with optimised denture and implant-retained overdenture. ***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.11 Eating difficult foodstuffs with implant-retained overdenture (*Appendix 3.1, question 30 / **Appendix 3.2, question 21)

Prior to implant treatment all ten patients had difficulties when eating food like apples and nuts, even with optimised conventional dentures. The patients experienced considerably fewer problems with the implant-retained overdenture; while four patients were still having a little difficulty, six indicated they were experiencing no difficulty, even with hard foodstuffs **(Table 3.23)**.

Q: How much difficulty do you have eating hard foods (like apples and nuts) with the new* (optimised) / implant-retained** denture		
	OCD*	OVD**
a) No difficulty	0	6
b) A little difficulty	4	4
c) Much difficulty	4	0
d) Extreme difficulty	2	0

Table 3.23: Eating hard foodstuffs with optimised and implant-retained overdentures. ***OCD** Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.12 Appearance with implant-retained overdenture (*Appendix 3.1, question 34 / **Appendix 3.2, question 25)

Nine patients reported improvement in their appearance following implant treatment. It must be assumed that this further improvement was as a result of increased denture stability leading to enhanced facial expression **(Table 3.24)**.

Q: **Would you say that the new*(optimised) / implant-retained ** denture has made your appearance?**	**OCD***	**OVD****
a) Much better	**6**	**9**
b) A little better	**2**	**1**
c) No change	**2**	**0**
d) A little worse	**0**	**0**
e) Much worse	**0**	**0**

Table 3.24: Apearance with optimised denture and implant-retained overdenture. ***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.13 Social interaction wearing implant-retained overdenture (*Appendix 3.1, question 32 / **Appendix 3.2, question 23)

There was little apparent change in patients' social lives after being provided with the optimised conventional denture. However, after implant treatment there was a significant shift and eight patients reported a much improved social life, and two patients reported some improvement in this respect **(Table 3.25)**.

Q: **Would you say that the new* (optimised) / implant-retained** denture has made your social life?**	**OCD***	**OVD****
a) Much better	**4**	**8**
b) A little better	**0**	**2**
c) No change	**6**	**0**
d) A little worse	**0**	**0**
e) Much worse	**0**	**0**

Table 3.25: Social interaction with optimised denture and implant-retained denture. ***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.14 Patients' perception of the implant-retained overdenture (*Appendix 3.1, question 25 / **Appendix 3.2, question 16)

There was a significant change in patients' perception after being provided with the implant-retained overdenture; six patients considered their implant prosthesis usually as part of themselves and four perceived it always as part of themselves **(Table 3.26)**.

Q: **Which statement most closely applies to how your new* (optimised) / implant-retained** denture feels in your mouth?**		
	OCD*	**OVD****
a) Always like a foreign body	**1**	**0**
b) Usually like a foreign body	**3**	**0**
c) Usually like part of yourself	**6**	**6**
d) Always like part of yourself	**0**	**4**

Table 3.26: Perception with optimised denture and implant-retained overdenture.
* **OCD**, Optimised complete denture.** **OVD**, Implant-retained overdenture.

3.4.15 Speech with implant-retained overdenture (*Appendix 3.1, question 31 / **Appendix 3.2, question 22)

While eight patients had experienced some speech difficulties with the optimised conventional dentures, no patients reported any difficulty with speech following implant treatment **(Table 3.27)**.

Q: **How much difficulty do you have in speaking with the new* (optimised) / implant-retained** denture**		
	OCD*	**OVD****
a) No difficulty	**2**	**10**
b) A little difficulty	**6**	**0**
c) Much difficulty	**2**	**0**
d) Extreme difficulty	**0**	**0**

Table 3.27: Speech with optimised and implant-retained mandibular overdentures.
* **OCD**, Optimised complete denture.** **OVD**, Implant-retained overdenture.

3.4.16 Denture wearing practises
(*Appendix 3.1, questions 37 & 38 / **Appendix 3.2, questions 30 & 31)

The majority of patients chose to wear their conventional dentures at all times, including overnight, against the professional advice given. It also appears that following implant treatment more patients chose to wear dentures at all times, again against professional advice. The increase in incidence of wearing the lower denture may have been linked to discomfort on the underside of the tongue caused by friction from the attachments(**Table 3.28).**

Q: **Do you wear your upper/lower denture (optimised-conventional* and implant dentures**)?**	**OCD***		**OVD****	
	Lower	**Upper**	**Lower**	**Upper**
a) All the time	**5**	**8**	**8**	**7**
b) Sometimes	**1**	**1**	**0**	**0**
c) Never	**1**	**0**	**0**	**0**
d)All times other than sleeping	**3**	**2**	**2**	**3**

Table 3.28: Wearing optimised denture and implant-retained overdentures.
***OCD**, Optimised complete denture. ****OVD**, Implant-retained overdenture.

3.4.17 Patient experience of surgery
(Appendix 3.2, question 32)
(Appendix 3.2, question 33)

From the responses represented in **Tables 3.29** and **3.30** it is clear that no patient would hesitate to have implant surgery again, with only the very slightest reservation with respect to advising others to follow in the same path.

Q: **If the clock were turned back, would you have the implant operation again?**	**Implant operation**
a) Yes	**10**
b) Perhaps	**0**
c) No	**0**

Table 3.29: Patients' responses with respect to implant surgery.

Q: **Would you recommend a friend to have implants placed?**	**Implant treatment**
a) Yes	**9**
b) Perhaps	**1**
c) No	**0**

Table 3.30: Patients' responses with respect to recommending a friend to have implant treatment

3.4.18 Overall satisfaction
(*Appendix 3.1, question 39 / **Appendix 3.2, questions 34)

Finally, the patients were asked to evaluate their overall satisfaction with both the optimised conventional denture and the implant-retained mandibular overdenture. There was a positive outlook with respect to the implant treatment **(Table 3.31).**

***Q:* How satisfied are you with the new* (optimised) / implant-retained** denture**		
Response	**OCD***	**OVD****
a) Not at all satisfied	**0**	**0**
b) A little bit satisfied	**6**	**0**
c) Very satisfied	**3**	**2**
d) Completely satisfied	**1**	**8**

Table 3.31: Overall satisfaction with optimised and implant-retained overdentures.
* **OCD,** Optimised complete denture.****OVD**,Implant-retained overdenture.

3.5 DISCUSSION

It is well documented that a high percentage of denture wearers have complaints about lower denture function (Smith & Sheiham, 1979; Berg, 1984; Bergman & Carlsson, 1985; Blomberg & Lindquist, 1983; Berg, 1988a; Harle & Anderson, 1993). The group of ten edentulous female patients in this study were referred to the Department of Prosthodontics at Glasgow Dental Hospital because of long-standing problems with conventional dentures, seeking the possibility of implant treatment. The reason for their referral was lack of stability of the mandibular dentures in function.

The self-administered dental function questionnaires were designed to evaluate patients' experience and satisfaction with their previous dentures, with optimised replacement complete dentures and with implant-retained overdentures, in order to allow subjective evaluation of denture function by the patients themselves. Questionnaires were designed with most questions having a five-point scale. The basis for choosing a five-point scale, rather than a three-point scale, was to provide more choice in cases where there may have been some degree of uncertainty.

After implant treatment and the conversion of the lower denture to an implant-retained overdenture, from self-assessment there appeared to be a remarkable change in the patients' ability to cope with the mandibular dentures. As there was no other change in the design of the dentures, it is likely that this will have been be due to the increased mechanical retention provided by the two implant fixtures with ball attachments. These findings are in accordance with the findings of Haraldson & Zarb (1988), Naert et al (1991), Harle & Anderson (1993), Cune et al (1994 a) and Wismeijer et al (1992, 1995, 1996).

All ten patients reported significant problems with their original lower dentures, which were reduced to some degree after the provision of the optimised conventional dentures. However, following implant treatment, a remarkable improvement was evident. There was a reported increase in patient comfort with the use of the optimised complete dentures, but all patients indicated that they were very comfortable after being provided with the implant-retained overdenture. There was a moderate reduction in the

occurrence of pain after the provision of the optimised conventional dentures, but following implant treatment all patients reported they were completely free of pain.

The concerns of the majority of patients that their original dentures might slip or fall out when eating and speaking were reduced moderately after the provision of optimised conventional dentures. Following implant treatment and after the patients have been provided with implant-retained overdentures, all reported a significant improvement in denture stability. It was apparent that the self-confidence of most patients was severely undermined with both the original and optimised conventional dentures. After implant treatment the majority reported a considerable improvement in self-confidence and all ten patients reported an enhanced sense of security. It seems likely that this will have resulted from the increase in stability of the lower denture which in turn will have led to an improvement in masticatory and social function. The improvement in self-confidence evident in this study is in accordance with the findings of Blomberg & Lindquist (1983), Wismeijer et al (1992), De Grandmont et al (1994) and Feine et al (1994)

The patients' perceptions of their ability to chew and eat effectively with dentures was affected to a large degree by treatment. It was strongly felt that the optimised complete dentures compared favourably with the original dentures. The most likely reason for this improvement with the optimised dentures is that the practical application of the standard principles of complete denture construction produced an improvement in denture stability. The application of these principles of complete denture design has been reported to be of importance for improvement of masticatory function by Thomson (1937) and Kapur & Soman (1965). Nevertheless, some patients still reported difficulties in chewing foods with the optimised conventional dentures and this finding is in agreement with Lindquist et al (1986), who stated that even with optimally designed and well constructed conventional complete dentures, many oral functions appear to be impaired. After the patients had been provided with the implant-retained overdentures there was a significant improvement in masticatory efficiency, and all ten patients reported they managed to eat considerably better than before, without any restriction on any type of food. Furthermore, with the optimised conventional denture, all patients reported difficulties when eating foods such as apples and nuts, while after implant treatment the majority of patients reported no such difficulties. Again it seems that the most likely explanation for this significant improvement in masticatory function

was the increase in denture stability provided by the dental implants. A significant improvement in masticatory function in this situation was found by Harle & Anderson (1993), Cune et al (1994 a), De Grandmont et al (1994), Wismeijer et al (1992,1995) and Geertman et al (1996 a & b).

Most patients reported an improvement in appearance with the use of optimised complete denture and there was a perception of a further improvement in appearance following implant treatment. This may be owing to the increase in the stability of the implant-retained overdenture and this corresponds with the research findings of Feine et al (1994) and De Grandmont et al (1994).

A considerable change in patients' social activity was reported after the provision of implant-retained overdentures. This effect was also reported by Wismeijer et al (1992, 1995, 1996) who evaluated this aspect of denture function in patients treated with mandibular implant-retained overdentures supported by ITI dental implants.

While it was apparent that all ten patients had perceived their original dentures as being foreign body in their mouths, more than half perceived their optimised dentures as part of themselves. After implant treatment, all ten patients considered their implant-retained overdentures usually or always as part of themselves. Furthermore, while it was reported that the optimised conventional dentures had made a moderate difference to the patients' lives, the implant-retained overdentures produced a significant difference to patients' lives, and four patients reported that the implant-retained overdenture had transformed their lives completely. It seems likely that this perception had resulted from the increased stability of the lower denture provided by the implant fixtures with a resultant improvement in masticatory and social function. This is in agreement with the findings of Blomberg & Lindquist (1983), Blomberg (1985), Albrektsson et al (1987) reporting on mandibular implant-supported bridges and with those of Haraldson et al (1988), Misch & Misch (1991), Wismeijer et al (1992) and Feine et al (1994) reporting on mandibular implant-retained overdentures.

All patients reported speech difficulties with their original dentures and there was a small reduction in speech problems with the use of optimised conventional dentures. However, all ten patients reported a significant improvement in speech after having been provided with implant-retained overdentures. This finding with respect to speech

improvement is in agreement with the findings of Haraldson et al (1988), De Grandmont et al (1994), Feine et al (1994) and Boerrigter et al (1995). It is clear that instability of the lower denture had a detrimental effect on speech quality in the patients' own assessment.

All patients reported they would not hesitate to undergo further implant surgery if this proved necessary, and it was a strong view that they would not hesitate to recommend this treatment option to friends. It is probable that this was because the patients experienced much less surgical discomfort than they had been expecting and the benefits exceeded their expectations. The same finding has been reported by Lindquist and Carlsson (1985), Kiyak et al (1990).

With respect to overall satisfaction, there was a moderate improvement with optimised conventional dentures, consistent with the findings of Gunne et al (1982), Berg (1984) and Berg (1988 a & b). Nonetheless, after patients had been provided with implant-retained overdentures it was evident that they were very much happier. The improvement in overall satisfaction for this group of patients may have been related to a number of factors:

- the improvement in the stability of the mandibular denture, provided by implant fixtures, may have been sufficient to reduce discomfort previously caused by the movement of the lower denture, which in turn will have led to an improvement in masticatory function, speech, comfort, aesthetics, self-confidence and social interaction.
- there may have been psychological benefit with an increased perception by the patients of the new implant-overdenture as an integral part of their bodies.
- there may be an element of bias introduced into the study by the patients' gratitude or desire to please the dental team, as has been reported by Reeve et al (1984), Berg (1988a) and Kent & Johns (1994).

It seems likely that an important factor in the patients' overall satisfaction was the frank and effective communication between the patients and the dental team throughout treatment and in the follow-up stages. All patients had been encouraged to talk about their problems and, at the same time, they had been prepared to have realistic expectations of treatment outcome. This atmosphere may have provided psychological support to a degree which improved the patients' overall satisfaction.

It is sometimes the case that patients treated with dental implants in the lower jaw may have some problems with their upper dentures (Naert et al, 1988). This effect was not found in the present study.

From the findings in the present study, the dental function questionnaire appeared to be a comprehensive and effective measure to assess the functional and psycho-social problems of edentulous patients. Patients were asked a series of general and specific questions about their dentures and it was noted that when patients were asked general questions the responses tended to be relatively positive. When specific questions were asked, the responses tended to be less positive. Direct and specific questions appear to be more effective in terms of identifying dissatisfaction or complaints, while evaluating the treatment outcome. Both kinds of question (general and specific) should be included in any self-assessment evaluation, to avoid under-reporting and to allow valid assessment of patients' perception of treatment.

3.6 CONCLUSIONS

The findings in this study showed that different treatment modalities in the rehabilitation of edentulous subjects may have an influence on various aspects of patients' life and these can be assessed by the use of clinically relevant dento-psychologico-social questionnaires. From the findings of this study a number of conclusions could be drawn.

1) After patients were provided with complete dentures of optimised design, there was a moderate improvement on the measured variables in comparison with patients' experience with their original dentures.

2) Following implant treatment, and after patients were provided with mandibular implant-retained overdentures, it was apparent from self-assessment that implant-retained overdentures improved the subjects' levels of masticatory function, comfort, self-confidence, speech, aesthetics, social interaction and overall satisfaction as measured in self-assessment.

3) A period of use of an optimised conventional denture prior considering implant treatment would appear to remain prudent and rational approach to treatment.

Of particular interest in the context of the overall assessment of these ten patients, is any correlation between the findings of this detailed, but subjective, patients self-assessment, and the more objective measure in denture function as described in Chapters Four and Five.

CHAPTER FOUR

BITE FORCE MEASUREMENT IN COMPLETE DENTURES AND IMPLANT-RETAINED OVERDENTURES.

4.1 REVIEW OF LITERATURE

4.1.1. METHODS OF ASSESSMENT OF THE MASTICATORY SYSTEM

The efficiency of the masticatory system can be assessed by measuring factors such as occlusal bite force, masticatory efficiency, maximum occlusal force and masticatory performance. Occlusal bite force has been defined as the force developed between antagonistic teeth by dynamic action of the masticatory muscles during the physiological action of mastication (Carr & Laney, 1987). Masticatory efficiency is generally defined as the number of masticatory strokes required to reduce food to a certain particle size during mastication (Bates et al, 1976; Tzakis et al, 1990). Maximum occlusal force (MOF), which is the greatest static force which can be applied voluntarily between antagonist teeth without any food being present, is often used as a measure of restorative effectiveness (Carr & Laney, 1987). Masticatory performance is assessed by examination of the particle size of food that has been chewed for a given number of strokes (Bates et al, 1976; Gunne et al, 1982). In addition to the above objective methods, subjective methods have been used to assess the individual's masticatory function by means of questionnaires and interviews (Carlsson, 1974; Haraldson et al, 1979 a & b; Carlsson, 1984; Harle and Anderson, 1993).

Patients with low tolerance of biting forces may have problems in masticating food, particularly in the case for elderly people with few or no natural teeth (Heath, 1982), and several devices for measurement of maximum bite force under these and similar clinical circumstances have been described in the literature. These can be used to give an estimation of bite forces values, helping clinicians to understand, or to predict, the outcome of treatments (Hagberg, 1987).

According to Carlsson (1974), prior to the 1950s at least 50 types of measuring device had been used for bite force measurement, and he indicated that the strain-gauge transducer had given the most reliable and accurate results. These measuring devices have progressed and evolved from crude stringed weight transducers to hydraulic devices, to more advanced wire and quartz strain-gauges. More recently, radiotelemetric methods, which operate on the piezo-electric principle of sound transmission, have been used (Carr and Laney, 1987).

4.1.1.1 Strain-gauge transducer

The earliest known attempt to measure bite force was carried out in 1681 by an Italian anatomist, Borelli, who apparently placed string weights over the molar teeth to measure the maximum weight that the mandible could lift (Jenkins, 1978). This was followed by the introduction of many other designs of apparatus, such as the gnathodynamometer used by Klaffenbach (1936) and Boos (1940). According to Manns et al (1979) and Carr & Laney (1987) the main problem in using the early strain-gauge transducers was the requirement for excessive vertical opening which prevented the development of full muscle force and so affected the measured bite force values. Another problem was patient apprehension resulting from fear of pain or breakage of the natural teeth.

In 1940, Boos used a gnathodynamometer to record the maximum occlusal force in edentulous patients. In his view one could determine the correct vertical dimension of occlusion using this instrument because, he suggested, maximum occlusal force was generated at the resting vertical dimension. A wire strain-gauge was introduced by Howell & Manly (1948), with a bite fork that allowed maximum occlusal force recording at an interocclusal distance of 7-10 mm. In the late 1950s, Howell & Brudevold (1950) developed a small size strain-gauge which helped avoid excessive vertical opening. The most popular apparatus currently in use for bite force measurement is the strain-gauge dynamometer, introduced by Floystrand et al (1982), and widely used since that time (Devlin & Wastell, 1985; Mericske-Stern et al, 1993, Mericske-Stern, 1994, Mericske-Stern et al,1995; Mericske-Stern & Zarb, 1996).

Bite force transducers have been used for the measurement of bite force either between single pairs of antagonist teeth or for bilateral force recording using a bite force transducer

between two occlusal forks. The measurements can be registered as a direct current (DC) signal on a millivoltmeter. The bilateral force recording method has been used by a number of Scandinavian researchers to study the average masticatory forces and the maximum occlusal forces generated by edentulous and dentate subjects and by patients who have had implant treatment (Helkimo et al, 1975; Haraldson & Carlsson, 1977; Lindquist & Carlsson, 1985; Lindquist et al, 1987).

Another method of using the strain-gauge, applicable only in edentulous subjects, is to incorporate a small quartz-gauge within the fitting surface of complete dentures (Brudevold, 1951; Yurkstas & Curby, 1953; Anderson, 1956; De Boever et al, 1978).

4.1.1.2 The combination of EMG registration and bite force measurement

Electromyography (EMG) is the recording of electrical activity produced by contraction of muscles. This can be achieved through the use of surface electrodes applied to the overlying skin, or by needle electrodes which are inserted through the skin into the muscle (Hoeds, 1948). Electromyography has been a useful clinical and research method in the analysis of the action of jaw muscles, particularly in combination with the cathode-ray oscilloscope and electronic recording apparatus (Yemm, 1977). Sub-maximum and maximum bite forces can be recorded by using a bite fork strain gauge transducer in relation to masseter and temporalis muscle activity, with or without the use of visual feedback. Studies of the relationship between myoelectric activity in masticatory muscles and measured bite force have shown a linear decrease in electromyography activity with reduction in recorded bite force (Haraldson et al, 1985; Hagberg et al, 1985).

4.1.1.3 Radiotelemetry system (sound transmission system)

Conant (1962) introduced this technique of using sound waves to measure bite force, and subsequently McCall et al (1978) used the telemetric device to monitor occlusal forces during function. Gibbs et al (1981) developed a method of measurement on the same principle that enabled maximum bite force and masticatory forces to be measured extraorally without the use of intraoral instrumentation. Sound vibration at a specific frequency was introduced at the subject's forehead with a piezo-electric crystal transducer

and the sounds, transmitted through the teeth, temporo-mandibular joints and muscles, were received by an accelerometer positioned at the chin. The greater the force between the mandible and the maxilla, the greater the amplitude of vibration. The practical advantage of this method is that jaw separation is not required.

4.1.1.4 Psychophysical measurement

Psychophysical methods have been used in assessments of the relation between the subjectively perceived and objectively recorded bite force by Wennstrom (1971 a & b, 1972). Wennstrom used a rating scale of either 7 grades (very weak, weak, rather weak, neither weak or strong, rather strong, strong, very strong), indicating that this psychophysical method may be suitable for clinical use in dentistry with both edentulous or dentate subjects.

4.2 FACTORS INFLUENCING OCCLUSAL BITE FORCE

Many attempts have been made to relate the ability to generate different levels of occlusal bite force to the characteristics of occlusion (Garner & Kotwal, 1973), facial height type (Taylor, 1936), muscle fibre type (Ringqvist, 1974), and electromyographic activity (Ahlgren & Owall, 1970). Recorded maximum occlusal force values, assessed using different measuring devices and under varying test conditions, have shown considerable variation and have been subject to widely differing interpretations (Hagberg, 1987) and it seems likely that the inconsistent findings are owing to a lack of control over variables that may affect occlusal bite force measurements. Some of these variables are described below.

4.2.1 Masticatory muscles strength and density

The maximum occlusal force that can be generated depends mainly on muscle strength and the quality of the supporting structures of the teeth, and the most important determinant of the maximum force which can be produced by a muscle is its cross-sectional area (Newton & Yemm, 1990).

The development of computed tomography (CT) has generally assisted investigators to determine the cross-sectional area of muscles. Weijis & Hillen (1984,1985) used computed tomography to measure the cross-sectional area of jaw muscles in male subjects and in cadavers, and they suggested that the magnitude of bite force that can be generated is proportional to the cross-sectional area of a muscle rather than its length.

Computed tomography techniques have been used to study age-related changes in human masseter and medial pterygoid muscles by Newton et al (1987) and Yemm & Newton (1988), who reported a significant decrease in the cross-sectional area and density of both muscles with age. Newton & Yemm (1990) and Newton et al (1993), using computed tomography, found that the cross-sectional area of masseter and medial pterygoid muscles showed a significant reduction with age and that the cross-sectional area of both muscles in edentulous subjects showed a greater decrease throughout the age range studied, in both male and female subjects, in comparison with dentate subjects.

Studies have indicated that there is adaptation in muscle tissue, particularly in muscle fibre size, following a change in functional conditions (Ringqvist, 1974; Maughan & Nimmo, 1984). In a study by Ringqvist (1974) the fibres of the temporalis muscle were examined in dissatisfied or satisfied denture wearers and in subjects with a natural dentition. Three types of fibres were identified. Type I fibres were characterised by slow contraction and high fatigue resistance, Type II fibres contracted more rapidly and were less fatigue-resistant, and a third intermediate type of fibre was identified. It has been postulated that in those patients who were dissatisfied with their dentures, Type II fibres were small in size compared to those patients who rated their dentures as satisfactory. In general, the number of Type II fibres was significantly lower in denture wearers than in those with a natural dentition and it has been suggested that Type II fibres are designed for powerful contractions and are activated mainly for strong biting efforts.

In view of significant differences in the muscle cross-sectional areas between dentate and edentulous subjects in the younger age group, it might be supposed that the greatest degree of muscle change following the loss of the natural dentition occurs over a relatively short period of time and certainly it is reported that there is a reduction in bite force as soon as

tooth loss occurs (Bergman & Carlsson, 1972; Bates et al, 1975a & b). However, this view point is not universally held and it has also been suggested that, with the appropriate prosthetic treatment, patients with immediate dentures can have maximum bite force values which approach those recorded for dentate subjects (Atkinson & Ralph, 1973; Ralph, 1979).

In a study to examine the time course of changes in muscle cross-sectional area following tooth loss and to establish the contribution of a successful functional prosthesis in maintaining adequate muscle function, Newton & McManus (1991) indicated that the retention of a small number of natural teeth as overdenture abutments appeared to play a significant role in the maintenance of oral function, as muscle bulk was greater in these cases than in equivalent edentulous subjects.

4.2.2 Age, sex, facial morphology and individual variations

Normally the strength of the masticatory muscles, like the other body skeletal muscles, tends to decrease after the fifth decade of life, and this process is more marked in women after the menopause than in men (Jones & Round, 1990). The ageing process in the masticatory muscles cannot be avoided, but it can be minimised until late age by the maintenance of a good natural dentition without significant tooth loss (Feldman et al, 1980; Klitgaard et al, 1990).

Several studies have reported on the differences between men and women with respect to occlusal bite force values and many researchers have found a significant correlation between maximum occlusal force and gender, with higher values in men than in women (Garner & Kotwall, 1973; Helkimo et al, 1975,1977; Bakke et al, 1990; Waltimo & Kononen, 1993). In a study of 125 subjects with natural teeth by Helkimo et al (1978) the mean values for maximum occlusal force were higher for men in the molar region (382 N) and in the incisor region (176 N), than they were for women (molars 216 N and incisors 108 N). However, other researchers have found no significant difference between the sexes (Linderholm & Wennstrom, 1970; Gibbs et al, 1981; Floystrand et al, 1982). It seems therefore that differences related to gender may be smaller than might be expected (Carlsson, 1974; Helkimo et al, 1977).

Decreased maximum occlusal bite force associated with increasing age appears mainly to be owing to age-dependent deterioration of the dentition (Helkimo et al, 1977), and the decrease in cross-sectional area and density of the jaw muscles (Weijis & Hillen, 1985; Newton et al, 1993). The majority of studies have shown a correlation between age and bite force. Bakke et al (1990) showed that there was a gradual increase in bite force from childhood, a constant level between 20 and 40 years of age and thereafter a decrease, particularly in women. However, as the general muscle mass and skeletal dimensions are established by early adulthood, variations in occlusal forces with increasing age could be expected to occur through changes in the state of the dentition or chewing demands on masticatory muscles, and not necessarily as a direct result of increasing age alone. Accordingly a decline in bite force is associated with tooth loss and in subjects with temporo-mandibular joint problems (Linderholm et al, 1971; Carlsson, 1974; Helkimo et al, 1977; Throckmorton et al, 1980; Ingervall & Bitsanis, 1987).

Several studies have indicated that occlusal forces do not seem to be closely related to general muscle strength or skeletal dimensions (Linderholm & Wennstrom, 1970; Helkimo & Ingervall, 1978; Bakke et al, 1990), while, on the other hand, Ringqvist (1973) and Proffit et al (1983), investigating occlusal force and its relationship with the facial skeleton dimensions, demonstrated by examination of lateral cephalometric radiographs that an increase in bite force was associated with a long mandible and a small gonion angle. Kiliaridis et al (1990) studied the relationship between facial morphology and bite force during different growth stages on six groups of healthy individuals of differing ages, and they concluded that growing individuals with a proportionally smaller lower facial height had the highest maximum bite force. Therefore, there is evidence that high bite force is associated with small face height, small gonial angle and madibular pronathism (Fields et al, 1984; Ingervall & Bitsanis, 1987; Waltimo & Kononen, 1994).

Carlsson (1974) reported that populations of lesser developed countries, who chew thoroughly, eat hard unprocessed food and use their teeth as tools in mechanical tasks, have higher maximum occlusal force values than populations from more developed societies. Waugh (1957) and Jenkins (1966) reported that Eskimo people have average maximal bite

force values in the range of 1470-1617 N, while the average maximum occlusal force among European and American populations was, on average, 588-735 N in the molar region (Gibbs et al, 1981).

4.2.3 The state of dentition and the supporting structures

Malocclusion and local pathological conditions of the teeth and the supporting tissues, including caries, pulpitis, periodontitis, tooth mobility and mucosa ulceration, are often causes of reduction in recorded maximum occlusal force (McDonald & Aungst, 1970; Carr & Laney, 1987).

Individuals with conventional complete dentures generally have shown low maximum occlusal force values, about a fifth or sixth of those found in the natural dentition (Ellsworth, 1975; Helkimo et al, 1977; Haraldson et al, 1979a; Hellsing, 1980; Glantz & Stafford, 1985; Lindquist et al, 1986). Limitations in maximum bite force for denture wearers may be due to masticatory muscle weakness, to reduced cross-sectional size of the jaw closing muscles in the edentulous subjects, to the pain of the denture-bearing soft tissue or to tilting and movement of dentures.

The maximum occlusal force values recorded in patients with removable partial dentures have been also been found to be less than the values produced for dentate subjects, but were greater than the values found with patients wearing complete dentures (Yurkstas and Emerson, 1964; Wennstrom, 1971a & b). Maximum occlusal force values measurements for patients with fixed partial dentures were found to be almost the same as in dentate subjects (Yurkstas et al, 1951; Carlsson, 1984). Various studies have shown occlusal force values in subjects treated with implant-supported prostheses (fixed bridges or retained overdentures) were higher than those found in subjects wearing conventional complete dentures (Knowlton, 1953; De Hernandez & Bodine, 1969; Haraldsson & Carlsson, 1977; Haraldsson et al, 1979 a & b; Lindquist & Carlsson, 1985; Albrektsson et al, 1987; Haraldson & Zarb, 1988; Falk et al, 1989; Lundqvist, 1993; Ueda et al, 1993; Carlsson & Lindquist, 1994; Mericske-Stern & Zarb, 1996).

4.2.4 Intra-oral variations

In dentate individuals, maximum occlusal force values have been found to vary from one part of the oral cavity to another; incisor region values being measured as approximately one third to one fourth of those found in the molar region by Worner (1939), Carlsson (1974), Helkimo et al (1977) and Hagberg (1987). The forces at the incisors have been found to vary between 140 N to 200 N (Hellsing, 1980). Bakke et al (1990) reported mean maximum occlusal force values in the molar region of about 522 N in men and 441 N in women. Waltimo & Kononen (1993, 1994) also reported higher bite force values for both men and women in the molar region, (847 and 911 N for men in two separate studies, and 597 for women) than in the incisor region (values of 287 and 569 N for men were recorded and 243 N for women). The authors considered that this was likely to be due to either strong masticatory muscles or to the facial morphology characteristics of the tested subjects, who showed small face heights.

The higher biting forces shown to be exerted by the molar teeth may be due to the larger surface area of the roots, according to Worner (1939), Carlsson (1974), Jenkins (1978) and Waltimo & Kononen (1993, 1994). Mansour and Reynik (1975) interpreted the action of the mandible as a Class III lever, with the fulcrum located at the centre of the condyle and with the position of the masticatory muscles most favourable for the provision of increased biting forces further back in the mouth. However, it has also been suggested that neurophysiological factors may be important, and it has been reported that the anterior teeth have a greater number of associated proprioceptive nerve endings than do the posterior teeth. These propriceptors may serve to protect the anterior teeth from over-load by negative feedback to the jaw closing muscles, leading to higher passive threshold values in the posterior teeth than the anterior ones (Van Steenberghe & De Vries, 1978)

Unilateral measurement of maximum occlusal force in subjects with natural teeth in the molar region has been found to produce approximately 50% of the values obtained with bilateral measurements (Pruim, 1979; Bakke et al, 1990) and no significant differences were found between bite force measurements on the right and left side of the dentitions of the same subjects by Molin (1972) and Bakke et al (1990).

Mandibular positioning appears to be an important factor influencing occlusal force measurement. Measuring maximum occlusal force with the mandible in lateral or protrusive excursion or in the retruded position has given lower bite force values in comparison with values recorded with the mandible in the intercuspal position (Leff, 1966; Marklaud & Molin, 1972; Molin, 1972).

4.2.5 The vertical separation of the jaws

This may also be an important factor in bite force measurement, particularly with respect to possible variations caused by the use of a bite fork and transducer in data gathering (Manns et al, 1979). Early occlusal bite force studies employed bulky devices which required wide separation of the jaws. Boos (1940) reported that vertical separation of the jaws and teeth, particularly opening beyond the free-way space, may have an effect on the magnitude of occlusal forces generated. This has been supported by investigation of length-tension curves for single muscle fibres; as a muscle fibre is stretched beyond its resting length it appears that initially more force potential is generated, but further stretching may result in a reduction of bite force generation capacity (Gordon et al, 1964; Manns et al, 1979).

In a study by Fields et al (1986) maximum bite force was measured in young adult males, with vertical opening varying between 10 and 40 mm in the incisor region. An increase in vertical opening to about 20 mm resulted in a progressive increase in maximum occlusal values. This was followed by a decrease in values to 30 mm, with a second increase to about 40 mm. These findings were in agreement with those of Manns et al (1979). In contrast Boos (1940) found the strongest bite force levels were reached when jaw opening was close to the free-way space dimension (2-4 mm). O'Rourke (1949) and Boucher et al (1959) have criticised Boos' findings, on the grounds that he conducted measurements in edentulous patients and there may have been uncontrolled variables, such as pain, apprehension and low tolerance, which may have influenced bite force value measurement.

It seems apparent from a number of other studies that the vertical opening of the jaws is most favourable for the generation of peak bite force when the interocclusal distance at the canine-molar regions is between 9 mm and 20 mm (MacKenna & Turker, 1978; Manns et al, 1979).

4.2.6 Patients with cranio-mandibular disorder (CMD)

Subjects with CMD symptoms, such as pain from the masticatory muscles or from the tempromandibular joints, were reported to generate lower occlusal force values than healthy subjects (Molin, 1972; Helkimo et al, 1975), and elimination of these symptoms was found to lead to an increase in bite force values. However, Hagberg et al (1985) found no significant differences between maximum bite force values for a control group of healthy subjects (10 subjects) and those with masseter muscle pain (30 subjects). It has been reported that after unilateral temporo-mandibular joint surgery there was no significant difference in bite force values between operated and non-operated sides.

4.2.7 Parafunctional habits (Bruxism)

The presence of clenching or grinding habits was found by Helkimo & Ingerval (1978) to increase the values of bite force measurements. They studied a group of male bruxists and another group of males without parafunctional habits and found higher bite force values in the bruxists. Gibbs et al (1986) reported that maximum bite force values in bruxists were as much as six times greater than those found in non-bruxists. Lindqvist & Ringqvist (1973) found no difference between maximum bite force values in young children who clenched their teeth and the control group of children without this parafunctional habit.

4.2.8 Head posture during measurement

Head posture was reported to influence the magnitude of the forces placed on the dentition by the muscles (Archer & Vig, 1985). However, Fields et al (1984) reported that at any given opening, changes in head posture did not significantly alter the vertical bite force values and they suggested that head posture does not directly affect the elevator muscles, but it may affect the activity and orientation of the depressor muscles of the mandible. It would appear that head posture should be controlled during bite force measurement because of its possible influence on jaw separation

4.2.9 Periodontal mechanorecptors

The human periodontal ligament contains the mechanosensitive free nerve endings of sensory fibres, known as periodontal mechanoreceptors, which have been found to be essential for masticatory function and oral tactile sensitivity. These mechanosensitive nerve

endings are divided into rapidly adapting and slowly adapting types, that respond when force is applied to the teeth and determine the magnitude and direction of the masticatory force. It was reported by Kizior et al (1968) that these mechanoreceptors are distributed evenly around the roots of the teeth, relatively close to the apex. The mechanoreceptors are divided into pain receptors which provide sensory feedback and presso-receptors which are involved in motor function (Siirila & Laine, 1963; Riis & Giddon, 1970). These mechanoreceptors are also found in the tempromandibular joints, muscles of mastication, oral mucosa and tongue (Jacobs & Van Steenberghe, 1991). The periodontal receptors have a protective function as they provide negative feedback to the forces developed by the jaw closing muscles during clenching efforts (Hannah & Mathews, 1968; Van Steenberghe & De Vries, 1978; Jacobs & Van Steenbeghe, 1991). Loss of the natural teeth results in loss of all periodontal receptors, while the other receptors in gingiva, alveolar bone and tempromandibular joints remain intact (Linden & Scott, 1989).

The likely influences of the mechanoreceptors around the teeth are in assisting in the control of masticatory forces, assisting in the recognition of the size and texture of objects placed between the teeth and assisting in monitoring the position of the mandible during function. Van Steenberghe & De Vries (1978) and Jacobs & Van Steenbeghe (1991) found that the full potential maximum occlusal force values between teeth were not normally estimated during recording due to the protective function of the periodontal ligament mechanoreceptors. These have a negative feedback action on the forces developed by the jaw closing muscles during voluntary maximum occlusal force efforts.
It has been reported that local anaesthetic infiltration of antagonist teeth before bite force measurement has led to an increase in bite force values due to the masking effects of local anaesthesia on the periodontal and pulpal receptors, which normally would have negative feedback effects on the jaw closing muscle activity (Van Steenberghe & De Vries, 1978). The finding of increased maximum occlusal force in incisor teeth after local anaesthetic administration was also reported by Hellsing (1980).

4.2.10 Psychological and mental status of individuals

Investigators have agreed that an important limiting factor in obtaining maximum occlusal force lies in the freedom of the subject from anxiety or physical discomfort (O'Rourke,

1949; Carlsson, 1974; Bates et al, 1975 a & b) and it has been stated that any change in the subject's mental condition during the recording session could influence the maximum occlusal force values achieved. In certain cases maximum occlusal force values are difficult to obtain, or may be presumed to be uncertain, in view of influences such as pain or fear of damaging the natural teeth or prostheses (Mericske-Stern et al, 1995; Mericske-Stern & Zarb, 1996).

4.2.11 Variation of measuring devices

The magnitude of maximal occlusal force measurements may vary depending on the method of measurement used. Lindquist & Carlsson (1985) found maximum bite force values of between 140 and 200 N when implant supported prostheses (fixed bridges) occluding with complete maxillary dentures, were assessed using the fork transducer. Others who used built-in strain gauge transducers (Falk et al, 1989; Lundgren et al, 1987) have reported higher bite force values. Falk et al (1989) reported mean maximal occlusal forces of about 340 N in patients with mandibular fixed bridges opposed by complete maxillary dentures using a technique which avoided any increase in the vertical dimension of occlusion and allowed for simultaneous measurements on eight locations on the prostheses.

4.3 MAXIMAL OCCLUSAL FORCE IN SUBJECTS WITH COMPLETE DENTURES

For many years clinicians and researchers have been aware of the adverse consequences of partial and complete edentulism with respect to oral function, and with respect to the psychological make-up of patients. Even the most effective rehabilitation with a conventional removable denture results in a diminished functional state in the oral cavity with impairments of masticatory efficiency, speech performance and tactile sensitivity discrimination (Carlsson, 1974; Carlsson et al, 1967; Bates et al, 1976; Mericske-Stern et al, 1993, 1995; Mericske-Stern & Zarb, 1996). In the majority of patients who have lost teeth, conventional treatment with partial or complete dentures provides an adequate reduction in this oral disability (Zarb et al, 1978; Hickey & Zarb, 1980). Nevertheless, a group of patients do not show any significant improvement in oral function and never fully accept removable prostheses, despite the use of high levels of clinical skill and the use of sophisticated techniques and materials (Carlsson, 1984; Berg, 1993). The causes of this are likely to be multi-factorial. The effects of ageing, anatomical limitations, psychological impairment, reduced sensory feed-back and, in some cases, sub-standard prosthetic treatment, may all play a part (Collett, 1955; Lefer et al, 1962; Litvak et al, 1971; Smith, 1976; Carlsson, 1984; Marbach, 1985; Van Wass, 1984).

Many studies have been conducted to investigate the relationship between the quality of dentures and improvements in oral function, though no close correlation has been found between these two variables (Langer et al, 1961; Yoshizumi, 1964; Carlsson et al, 1967). Patient self-assessment questionnaires for evaluating masticatory function have been used and the results have indicated a decrease in these functions in complete dentures wearers compared with dentate subjects (Osterberg & Carlsson, 1979; Laine, 1982). According to these studies, age *per se* appears to have little direct effect on chewing ability, the state of the dentition being a more important factor. Following tooth loss objective measurement has often shown chewing efficiency to be reduced, despite the fact that in many instances patients themselves often regard masticatory function as satisfactory when measured by self-assessment (Bergman & Carlsson, 1972; Carlsson, 1974; Helkimo et al, 1978; Bates et al, 1976; Heath, 1982). It has been reported that the correlation between subjectively and

objectively-assessed efficiency of masticatory function is not very strong (Gunne et al, 1982; Heath, 1982) and it seems that self-assessment of masticatory efficiency is, in general, too positive when compared with the results of objective measurement (Carlsson, 1984).

The mechanism of dealing with normal functional and parafunctional loads is totally different in edentulous individuals than it is in dentate individuals, and the primary reason suggested for this is the loss of periodontal support. Watt (1960) estimated the mean area of the periodontium in each intact dental arch to be 45 cm^2, but in the edentulous maxilla the supporting area of the oral mucosa was measured as 23 cm^2 and as 12 cm^2 in the edentulous mandible. The loss of alveolar bone is primarily a response to tooth loss, but the size of the residual edentulous alveolar ridge can be compromised even further as a result of the continuous ageing process, by denture wearing, particularly if the denture design is inadequate, and by hormonal or metabolic disturbances (Atwood, 1971; Tallgren, 1972; Kalk & de Baat, 1990). Many of the principles of complete denture design, such as full functional extension of the denture bases, the correct contour of the denture polished surface to achieve muscular balance and the setting of teeth in balanced occlusion, have been reported to be of importance for achieving masticatory efficiency (Thomson, 1937; Kapur & Soman, 1965), but several studies have concluded that edentulous individuals are severely handicapped with respect to bite force and that even clinically satisfactory or optimally constricted complete dentures are poor substitutes for natural teeth (Haraldson et al, 1979a; Gunne et al, 1982; Michael et al, 1990).

Peak bite force values have been found, to be lower in individuals with conventional complete dentures than in dentate subjects (Ellsworth, 1975; Helkimo et al, 1977; Haraldson et al, 1979a; Heath, 1982; Glantz & Stafford, 1985; Williams et al, 1985; Michael et al, 1990). These maximum occlusal force values for edentulous individuals have been, on average, one-third to one-sixth of the values for individuals with intact dentitions. Reported maximum occlusal force values in adults wearing complete dentures have varied from 77 to 196 N (Haraldson et al, 1979a; Ralph, 1979; Meng & Rugh, 1983; Colaizzi et al,1984).

It is noteworthy that the maximal occlusal force values were found to be higher in patients with mandibular overdentures supported by roots [339N] than patients wearing conventional complete dentures [130N] Meng & Rugh, 1983), and Sposetii et al (1986) reported an increase in maximum occlusal force values from 226 N to 745 N after placement of precision attachments in a mandibular overdenture.

4.4 MAXIMAL OCCLUSAL FORCE IN SUBJECTS WITH IMPLANT-PROSTHESES

Since the early 1950s, attempts have been made to measure maximum occlusal force values in patients with subperiosteal implants and compare these with patients wearing conventional complete dentures. In two early studies, it was reported that implant patients exerted two to two and a half times more force than patients with conventional dentures (Knowlton, 1953; De Hernandez & Bodine, 1969).

The introduction of osseointegrated dental implants (Branemark et al, 1969) has resulted in substantial advancements in prosthetic dentistry providing greater retention and support for dental prostheses. Functional improvements have been demonstrated in studies examining bite force, chewing efficiency and speech (Haraldson & Carlsson, 1977; Lindquist & Carlsson, 1985; Lundgren et al, 1987; Albrektsson et al, 1987; Haraldson & Zarb, 1988; Haraldson et al, 1988; Falk et al, 1989; Lundqvist et al, 1992 a & b; Lundqvist, 1993; Carlsson & Lindquist, 1994; Mericske-Stern et al, 1993,1995; Mericske-Stern & Zarb, 1996).

Carr and Laney (1987) compared maximum occlusal force values achieved with conventional complete dentures with the findings for mandibular fixed bridges supported by dental implants and opposed by maxillary complete dentures, and found significant improvements after implant treatment. The maximum occlusal force values, which ranged from 20 to 113 N in denture-wearing subjects, were found to increase to between 45 and 256 N in the same individuals with implant-supported fixed prostheses. The longer that individuals had been edentulous, the less was the increase in maximum occlusal force

values following implant treatment. Patients who had been edentulous for more than 15 years showed an average increase in maximum bite force of 24 N, compared with 94 N in patients who had been edentulous for less than 15 years. This finding seems to suggest that the longer period of time that an individual is without natural teeth, the longer it takes to recapture or regain the lost functional capacity. The degree to which this is recaptured depends on factors such as the age of the patient, the number of years of edentulism, neuromuscular adaptive capacity, the length of time with the new prostheses and the type of prostheses (Helkimo et al, 1977; Lindquist et al, 1987; Bakke et al, 1990).

In 1994, Carlsson & Lindquist reported on maximal occlusal forces and masticatory efficiency over a 10 year period in 23 edentulous patients each, of whom had been treated with a full-arch mandibular fixed-bridge supported by osseointegrated implants and opposed by a maxillary complete denture. Thereafter, nine of these patients also received full-arch maxillary fixed-bridges. The results showed that after placement of the implant-supported fixed-bridges in the mandible there was a substantial improvement in maximum occlusal force values and in masticatory function reflected both in the patients' self evaluation and in functional measurement tests. These findings were in agreement with bite force studies of mandibular fixed-bridges opposed by maxillary complete dentures by Haraldson & Carlsson (1977), Lindquist & Carlsson (1985), Jemt & Carlsson (1986), and Book et al (1992). There were no significant differences in maximum bite force values between patients who had only mandibular fixed-bridge prostheses and those with fixed-bridges in both jaws. For both groups the bite force values increased with time, indicating that adaptation to the new prosthetic situation is a gradual process. Similar findings were also reported by Lindquist & Carlsson (1985), Haraldson & Zarb (1988) and Book et al (1992).

Bite force and other oral functions in overdenture patients have been investigated by Haraldson et al (1988) by means of functional assessment and the use of self-assessment questionnaires. Nine subjects, who had been treated by the construction of mandibular overdentures retained by two to four implant fixtures which were opposed by conventional maxillary complete dentures, were assessed. The subjective and the objective evaluations were carried out with the conventional complete dentures prior to implant treatment and

were repeated one year after implant treatment. Measurement of bite force values was undertaken in the incisor, canine and premolar areas, during gentle biting, while chewing and with maximum occlusal force. Questionnaire results showed that these patients, treated with implant-retained overdentures, were satisfied with respect to denture stability and chewing ability. The average maximum occlusal force values increased from 75 N before treatment to 132 N after conversion of the patients' original mandibular dentures to overdentures retained by bar attachments on osseointegrated dental implants.

The retention of natural roots beneath complete dentures has been reported to maintain ridge form by reducing the ongoing resorption process of the residual alveolar processes (Atwood, 1971; Tallgren, 1972). Residual roots also provide for sensory feedback because the receptors of the periodontal ligament are maintained. These receptors also contribute to the co-ordination of motor activity during chewing, and they provide a protective function because of their inhibitory reflex action in the case of potential over-loading (Van Steenberghe & de Vries, 1978; Fenton & Lundqvist, 1981; Lundqvist & Haraldson, 1984; Jacobs & Van Steenberghe, 1991).

A comparative study was carried out by Mericske-Stern et al (1993) to investigate the maximal occlusal forces generation in patients treated with mandibular overdentures retained either by implants or by natural roots with gold copings and precision attachments. Recordings were undertaken unilaterally in the first-premolar, second-premolar and first-molar regions, measured by the use of a miniature bite force transducer, as designed by Floystrand et al (1982). The results revealed that there were no significant differences between the two groups tested with respect to maximum bite force generation. The average maximum bite force value of 142.6 N was found for patients wearing implant-retained overdentures, and 131.2 N was the average maximum bite force value for patients wearing overdentures retained by natural roots. Mericske-Stern noted the similarity in average maximum bite force values for two the groups, the absence of the periodontal ligament in the implant subjects did not lead to a significant increase in bite force. It could be the case that other receptors in the denture-bearing tissues, tempromandibular joints or the tongue could be responsible for any negative sensory feedback occurring under clenched loads in edentulous patients with implants.

Mericske-Stern et al (1995) conducted a further study using similar methods to measure the maximum occlusal force in partially dentate subjects who had been restored using fixed bridges or single crowns supported by osseointegrated dental implants. The control group consisted of fully dentate subjects with healthy natural teeth. Maximum occlusal force was measured with the use of a transducer placed between antagonist implant/tooth pairs in the test group and tooth/tooth pairs in the control group. The results revealed that higher maximal occlusal force values were measured in the fully dentate subjects, with an average value of 450 N. The average maximum occlusal force values for the subjects with fixed prostheses supported by implants was 300 N. Examined in conjunction with the results from the 1993 study, it seems that maximum occlusal force values in patients wearing overdentures retained either by implants or natural teeth were less than the maximum occlusal force values found in fully dentate subjects and partially dentate subjects restored with the use of implant-supported fixed-bridges or single crowns. The lower bite force values found in those patients with mandibular implant-retained overdentures opposed by maxillary conventional dentures may be owing to the presence of conventional dentures in the maxillary arch, which could be a limiting factor with respect to the level of the maximum occlusal bite force generated.

Mericske-Stern & Zarb (1996) carried out further investigation of maximum occlusal force and assessment of oral tactile sensibility in edentulous patients treated with mandibular fixed implant-supported prostheses and maxillary complete dentures, using similar methods and the same type of bite force transducer as in the previous studies of Meriscke-Stern et al in 1993 and 1995. However in the two earlier studies the ITI® implant system had been used, while the Branemark implant system was used in the 1995 study. The results of these studies were compared and it was reported that maximum occlusal force values ranged from 66 to 272 N in the three test locations (first and second premolar and first molar regions) and that the bite force values found in the 1996 study were less compared with the two earlier studies, but they were comparable to those recorded in overdentures patients retained by two implants (Mericske-Stern et al, 1993). Therefore, they concluded that the number of intra-formaminal implants does not appear to have an influence on the magnitude of bite force generated when compared with overdentures retained by two

implants. The presence of complete denture in the opposing arch appears to be a significant factor contributing to reduced maximum occlusal force values, particularly when opposed by an implant fixed prostheses.

4.5 SUMMARY OF THE REVIEW OF LITERATURE

In summary, it seems apparent from the literature that rehabilitation with removable partial or complete dentures provides a poor functional alternative to the natural dentition. Several studies have confirmed that edentulous individuals are severely handicapped in terms of bite force and tactile sensibility, and even clinically satisfactory complete dentures appear to be poor substitutes for the natural teeth (Carlsson, 1974; Carlsson et al, 1967; Bates et al, 1976; Haraldson et al, 1979a; Gunne et al, 1982; Lindqvist et al, 1986; Michael et al, 1990). Despite the apparent satisfaction of edentulous subjects in some studies relying on subjective self-assessment (Bergman & Carlsson, 1972; Bates et al, 1976; Gunne et al, 1982), oral function as assessed in objective measurement has been found to show maximum occlusal force values that were on average only one-third to one-sixth in magnitude of those found in dentate individuals (Haraldson et al, 1979a; Meng & Rugh, 1983; Glantz & Stafford, 1985; Michael et al, 1990). The variation in values reveals that recording of maximum bite force is dependent on many factors. Masticatory muscle strength, state of the dentition and supporting structures, age, sex and facial morphology, psychological affects, increased jaw separation, replacement of natural teeth with artificial substitutes, parafunctional habits, variation among measuring device and their position within the dental arch, the number of teeth involved during recording, jaw muscle pain and cranio-mandibular disorders have all been considered to be factors of importance in limiting of maximum bite force generation capacity (Carr and Laney 1987; Newton et al, 1993; Waltimo & Kononen, 1994). The sensation of discomfort from the tissues supporting dentures, particularly in the lower jaw, is likely to be the significant limiting factor for maximum occlusal force generation with conventional complete dentures (McDonald & Aungst, 1970; Bergman & Carlsson, 1985; Cawood & Howell, 1991).

It is evident from the literature that the absence of a periodontal ligament and its associated receptors around dental implants has led to an impairment in active and passive tactile sensibility (Lundqvist & Haraldson, 1984; Jacobs & Van Steenberghe, 1991; Mericske-Stern et al, 1993,1995; Merciske-Stern & Zarb, 1996). It has been postulated that the absence of periodontal receptors around dental implants and the loss of an associated inhibitory reflex mechanism should produce relatively high bite force values (Merciske-Stern & Zarb 1996). However, from studies in this field it seems that lower than expected maximum occlusal force values are found following implant treatment (Mericske-Stern et al, 1993,1995; Mericske-Stern & Zarb, 1996). Of course, other factors might be contributing to the low maximum bite forces recorded; age-related changes in muscle cross-sectional areas and density of the jaw muscles may be important in this respect (Newton et al, 1987,1993; Yemm & Newton, 1988), as may discomfort underneath dentures (McDonald & Aungst, 1970; Bergman & Carlsson, 1985; Cawood & Howell, 1991). Psychological factors such as concern about causing damage to the implants or to the prosthetic components, or the presence of other mechanoreceptors in the denture-bearing tissues, tempromandibular joints or the tongue might also play a role in the production of the relatively low levels of maximum bite force values seen (Mericske-Stern & Zarb, 1996). Most of the above studies have been carried out on patients with mandibular osseointegrated fixed bridges or implant-retained overdentures which have been opposed by maxillary conventional complete dentures. The presence of a conventional denture may be a limiting factor with respect to the magnitude of the maximum occlusal force values recorded (Mericske-Stern & Zarb, 1996).

4.6 AIM OF THE PRESENT STUDY

The present study was undertaken to measure maximum occlusal force values obtained using a bilateral bite-fork transducer in edentulous subjects wearing conventional complete dentures in both jaws and to repeat maximum occlusal force measurements in the same group of subjects following treatment to provide retention for the mandibular dentures by the use of two ITI® implant fixtures. It was a major aim of this study to use a controlled and effective method of bite force measurement, to ensure that clinical variation was minimised such that there were no other structural or design changes in the dentures, and to link the findings with the length of edentulousness.

4.7 MATERIALS AND METHODS

4.7.1 Patient selection

Ten edentulous patients were selected from the waiting list of the Prosthodontic Department at the University of Glasgow Dental Hospital and School. Several studies have reported on the differences between men and women with respect to occlusal bite force values and many researchers have found a significant correlation between maximum occlusal force and gender, with higher values in men than in women. Therefore in this study in order to obtain a relatively uniform experimental group, the patients selected were female and over the age of 55. The age range was from 57 to 72 years (mean 66.3 years). The patients had been referred to the Department of Prosthodontics because of long-standing problems with conventional dentures. All complained of instability of mandibular dentures and many had difficulties during eating (eight patients) and speaking (four patients). Discomfort from the tissue under the mandibular denture was reported by seven patients and seven patients also reported psycho-social distress. Most of these complaints were attributed to the loss of stability of the mandibular dentures in function. The patients in the group had been edentulous for between four and 35 years (mean 19.5 years), and each patient had had at least four different sets of dentures.

All patients underwent clinical examination to assess mucosal health and to examine potential implant sites in the anterior mandible with regard to ridge form and the presence of keratinised mucosa. Panoramic radiographic examination (OPT) was undertaken to

evaluate bone quality and quantity in the potential implant sites, to help identify the location of the mental foramina and inferior dental nerve, and to give a wider assessment to exclude the presence of pathological lesions or root fragments. Lateral cephalometric radiographs were used in each case, to help clarify alveolar ridge width and sagittal plane orientation in the anterior mandible.

There were no general medical contra-indications to implant treatment and during the selection procedure each patient was informed of the clinical stages involved in the surgical and prosthetic aspects of treatment, supported by illustration of treated cases. Possible complications of treatment were fully explained as was the purpose of the study.

4.7.2 Clinical procedure

Initially all patients were provided with conventional complete dentures designed with full base extension and adequate interoccusal clearance. Jaw relations were recorded with the mandible in the retruded contact position and care was taken to ensure that tooth position was in balance with the surrounding musculature. The denture teeth were set in balanced articulation on a semi-adjustable articulator. After delivery of the dentures the patients were kept under close review for one month, final adjustment to the occlusal and impression surfaces of the denture being carried out as required.

Approximately three months after the completion of conventional denture treatment, initial assessment of denture function was carried out by the use of bite force transducer **(4.7.3, 4.7.4)**. Thereafter two ITI® transmucosal dental implants (Institute Straumann, Switzerland) were placed, two for each of the ten patients in this study. The fixtures were placed in the intra-foraminal region of the mandible. As is normal for the use of this system, there is no need to expose the fixtures after osseointegration has been achieved. During the three month healing period required for osseointegration the patients' dentures were modified and a resilient lining material was placed to help absorb the forces generated during function.

After completion of the healing period the mandibular denture constructed at the beginning of treatment, and then used as a temporary prosthesis, was modified by the

addition of Dalbo matrix attachments **(Fig.4.1)** to engage titanium retentive anchors placed on the implant fixtures **(Fig. 4.2)**. Care was taken to optimise the standard of clinical and laboratory techniques in the surgical and prosthetic phases of treatment. Of the twenty fixtures placed, sixteen were hollow cylinder implants and four were hollow screws implants, with intraosseous lengths of 10 or 12 mm **(Table 4.1)**. After a two month settling in period functional assessment by bite force measurement was repeated.

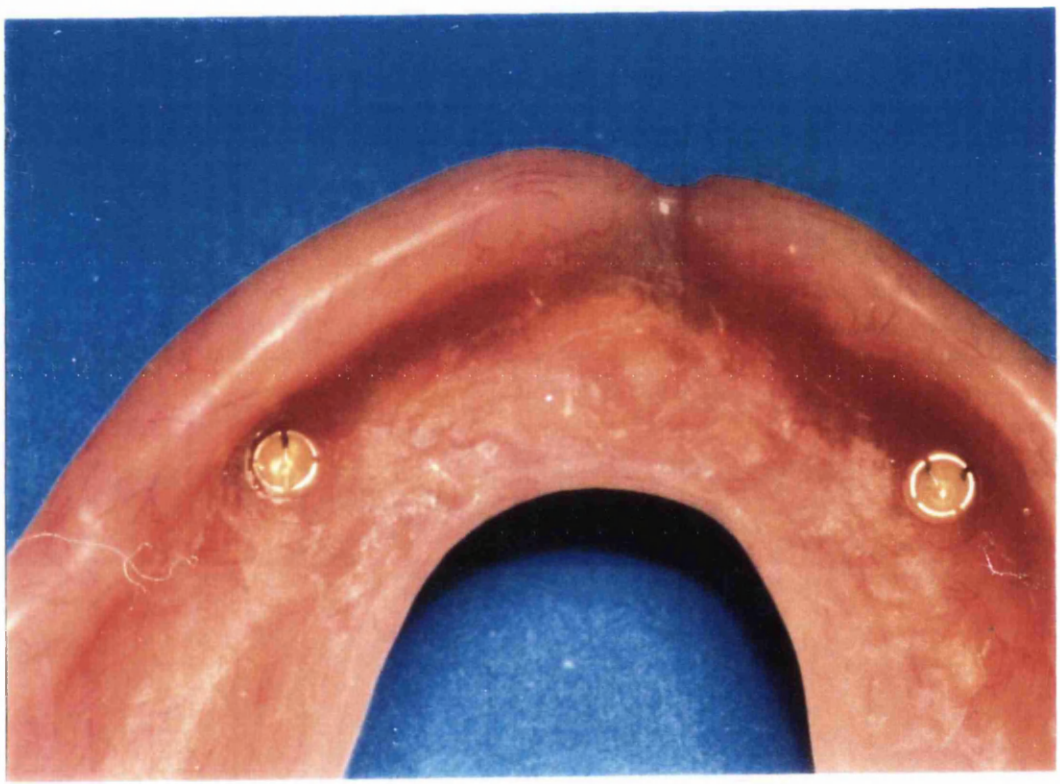

Fig.4.1: Dalbo matrix in-situ

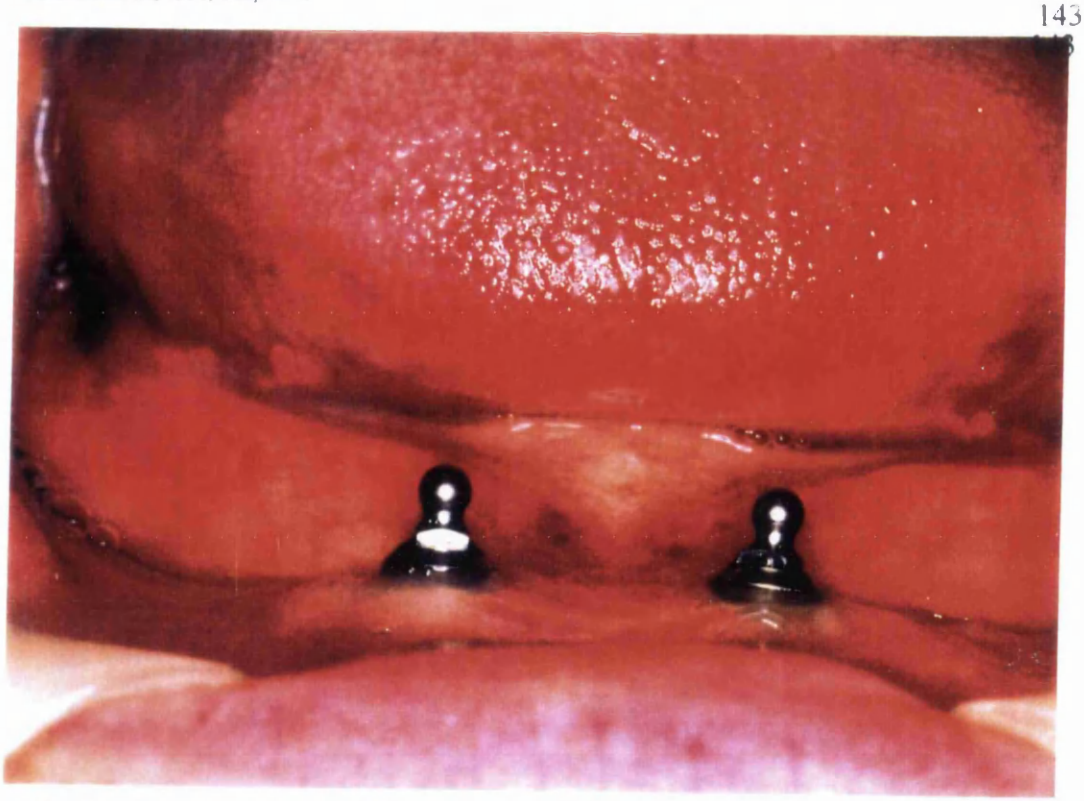

Fig.4.2: Retentive ball attachment

Type of Fixture		Fixture length	
H.C*	16	10 mm	14
H.S**	4	12 mm	6

Table 4.1: Fixture type and length
* **HC**, hollow-cylinder implant
** **HS**, hollow-screw implant

4.7.3 Bite force measuring device

The transducer used in the study was made following co-operation between staff in the Prosthodontic Department of Glasgow Dental Hospital and the Engineering Department at the Southern General Hospital, Glasgow. It was a T-shaped bilateral transducer (80 mm long, 20 mm wide, 10 mm thick) specially designed for use with edentulous patients. It was constructed from two stainless steel metal beams joined together with bolt-head screws in form of a T-shape. Two strain gauges were cemented on the long arm of one of the beams and wired to form a Wheatstone bridge circuit. A Wheatstone bridge circuit is commonly used for the rapid and precise measurement of resistance. The part of the beam with the strain gauges attached was

coated with a silicone rubber compound in order to effect a watertight seal when the gauges were exposed to saliva. When a load was applied to the beams, the mechanical deformation altered the resistance of the strain gauges and the change in signal voltage was used to provide a measure of force through the electrical resistance changes of the strain gauges transducer **(Fig 4.3)**. The transducer was connected to a digital display unit **(Fig 4.4)**, which measured force in units of a kilogram.

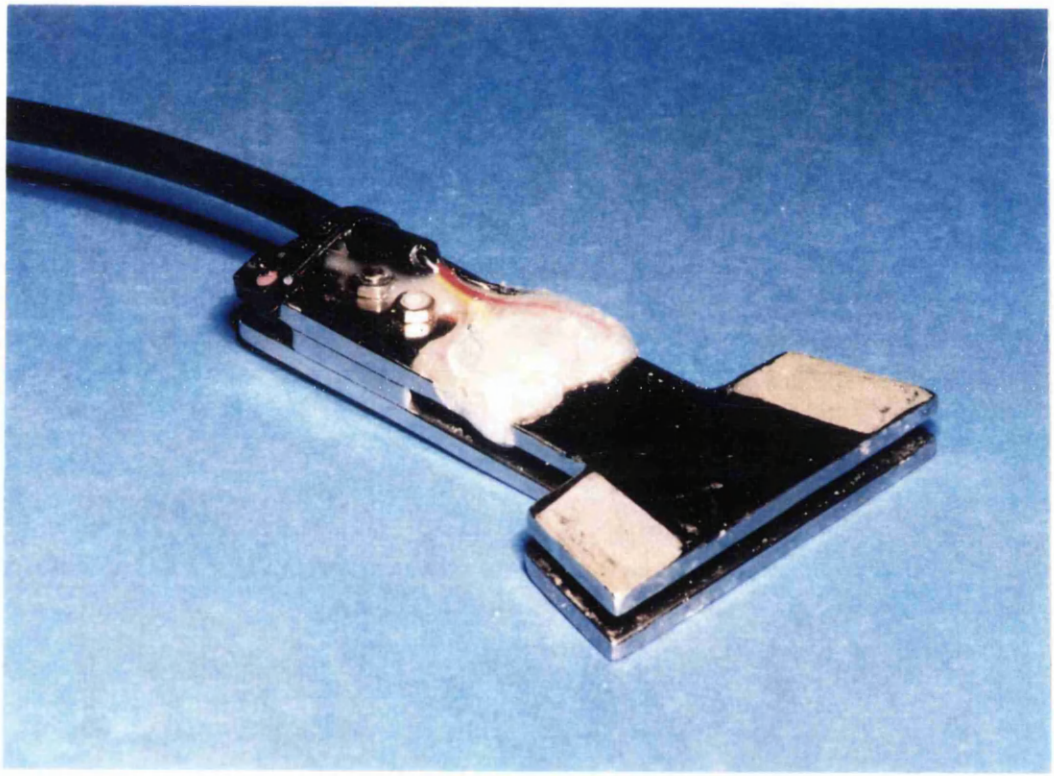

Fig.4.3: Bite force transducer

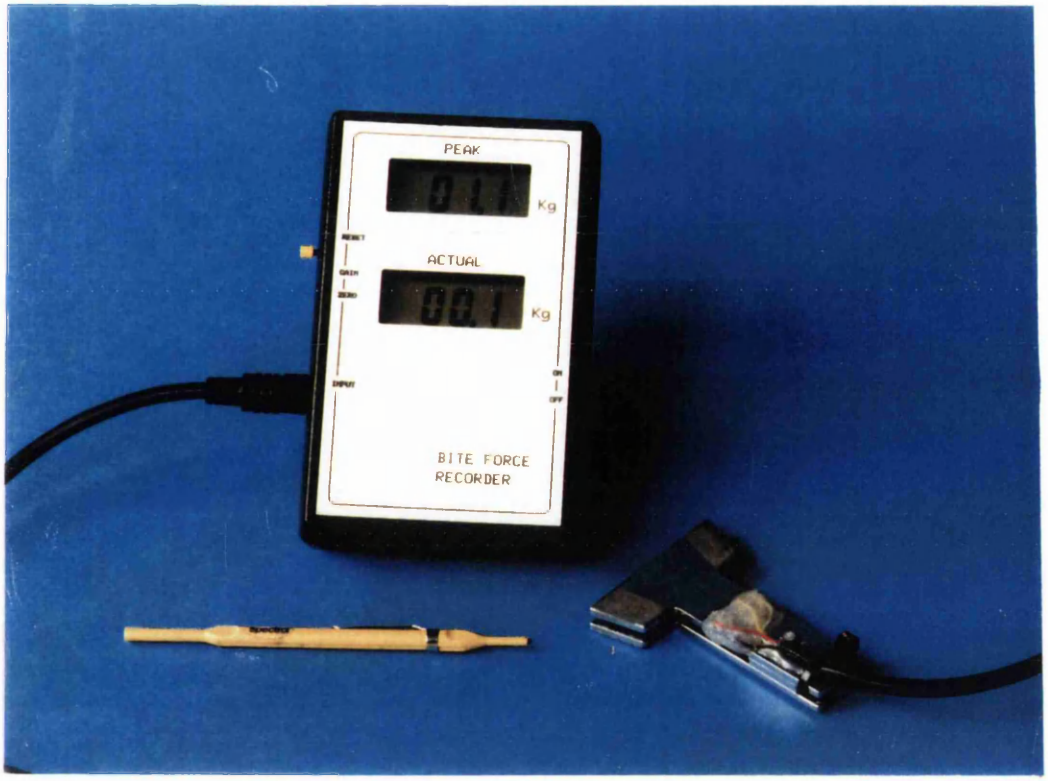

Fig.4.4: The transducer, screw driver and the display unit

The transducer was calibrated and checked on three occasions; at the beginning before starting the measurement, midway through the study and after completion of the study. Manually applied dead weights of 5, 10, 15, 20 and 25 Kgs were used in the calibration procedure.

Before bite force measurement was undertaken, for each of the ten patients in the study, alginate impressions were taken of both dentures and stone casts made. The "best biting position" for each patient was recorded using an acrylic resin template which replicated the dimensions of the transducer to be used in bite force measurement **(Fig 4.5)**. A thin layer of softened wax was applied on both sides of the template and the patient induced to close in the retruded arc of closure. The T-shaped template was located in a central position to give a stable bi-lateral contact of the dentures. This jaw relation registration was used to allow mounting of casts of the patients' dentures on a simple hinge articulator with an interocclusal opening of 10 mm **(Fig 4.6)**. A customised acrylic index was then made in self-cure acrylic resin to provide for pre-determined and reproducible placement of the transducer during bite force recording.

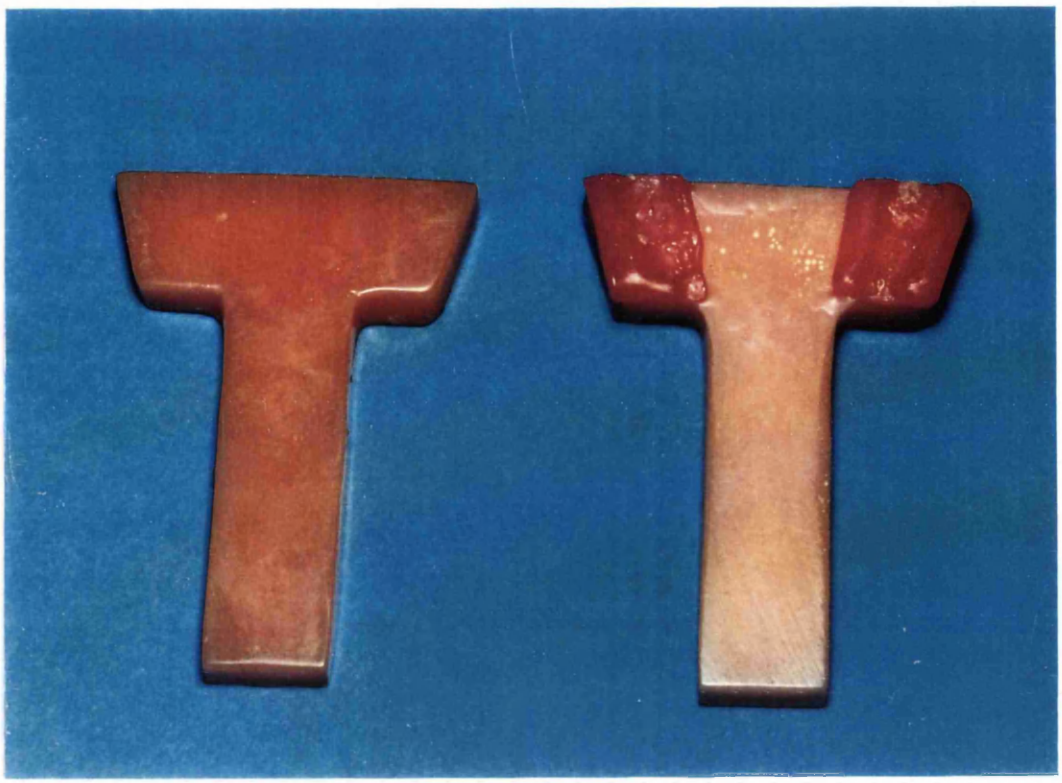

Fig.4.5: The acrylic T-shape resin template

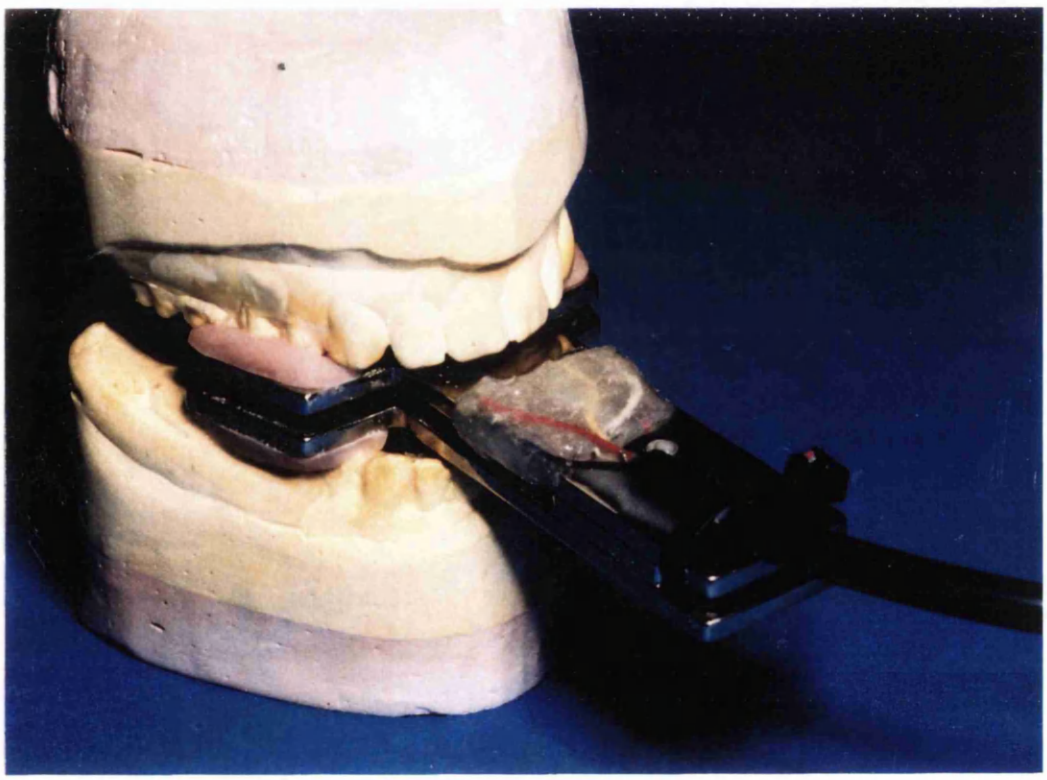

Fig.4.6: The transducer and acrylic index on a simple Hinge articulator

4.7.4 Measuring procedure

Bite force measurement was not undertaken until patients were free from discomfort and able to produce clenched and occluded loads without pain. Prior to bite force measurement, the health of the oral mucosa was evaluated to check for signs of inflammation, irritation or any conditions which could preclude production of voluntary maximum occluding force during the measurement procedures.

The format for bite-force was explained and the patients were seated in an up-right position in a dental chair with comfortable head support **(Fig 4.7)**. A trial recording was undertaken to allow the patients to become accustomed to the apparatus. The transducer was positioned precisely between the antagonist pre-molar and first molar teeth of the dentures using the prepared acrylic template. To record the maximum biting force each patient was asked to bite as hard as possible on the metal fork for two seconds and relax. For each patient six repetitive recordings at maximal biting force were made, with the patients allowed to relax for 15 second between each recording. During the clenching activity the patients were encouraged verbally to produce the greatest biting force they could.

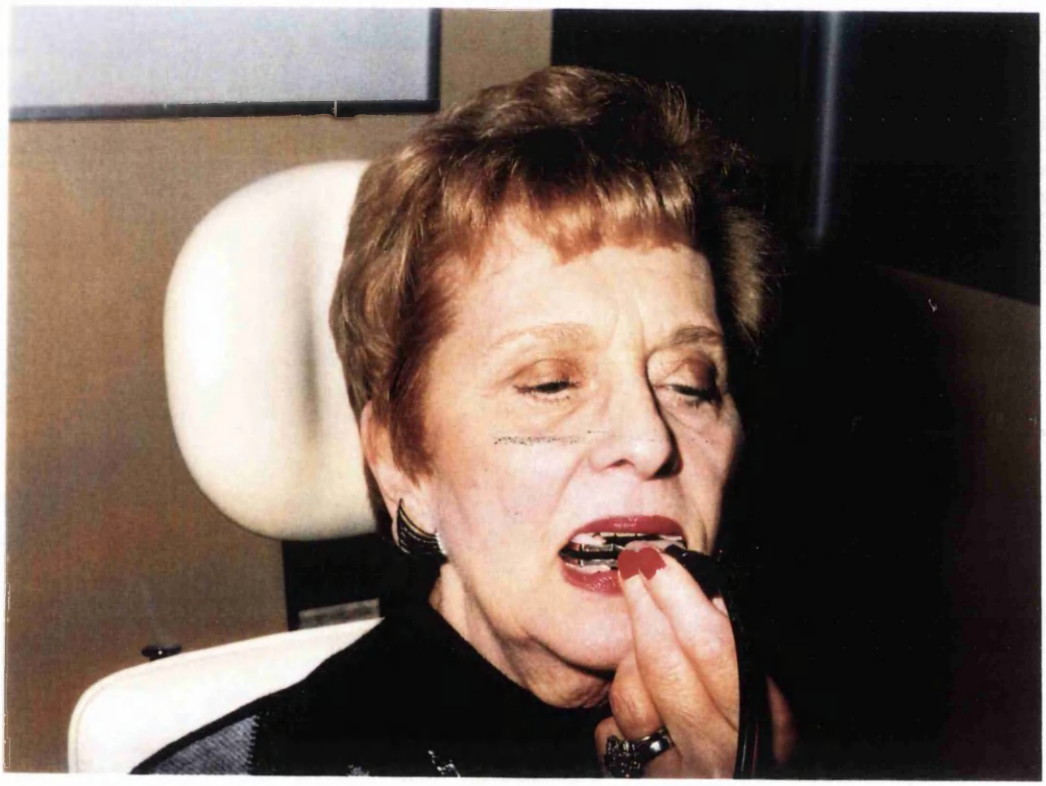

Fig.4.7: Bite force measurement in the dental chair

4.7.5 Measuring the denture bearing area.

At initial analysis it was observed that the greatest bite force values appeared to be associated with the mandibular complete dentures with the largest tissue contact area, and it was hypothesised that the size of the denture bearing area may have been a factor contributing to the bite force values obtained. In order to further assess this factor the mandibular denture bearing area was calculated for each patient. An alginate impression of the fitting and peripheral surfaces of each lower denture was made and a stone cast produced. The denture bearing area was marked with a fine tipped marker on the cast with the help of anatomical landmarks such as buccal, labial and lingual freni and the retro-molar pads **(Fig 4.8).**

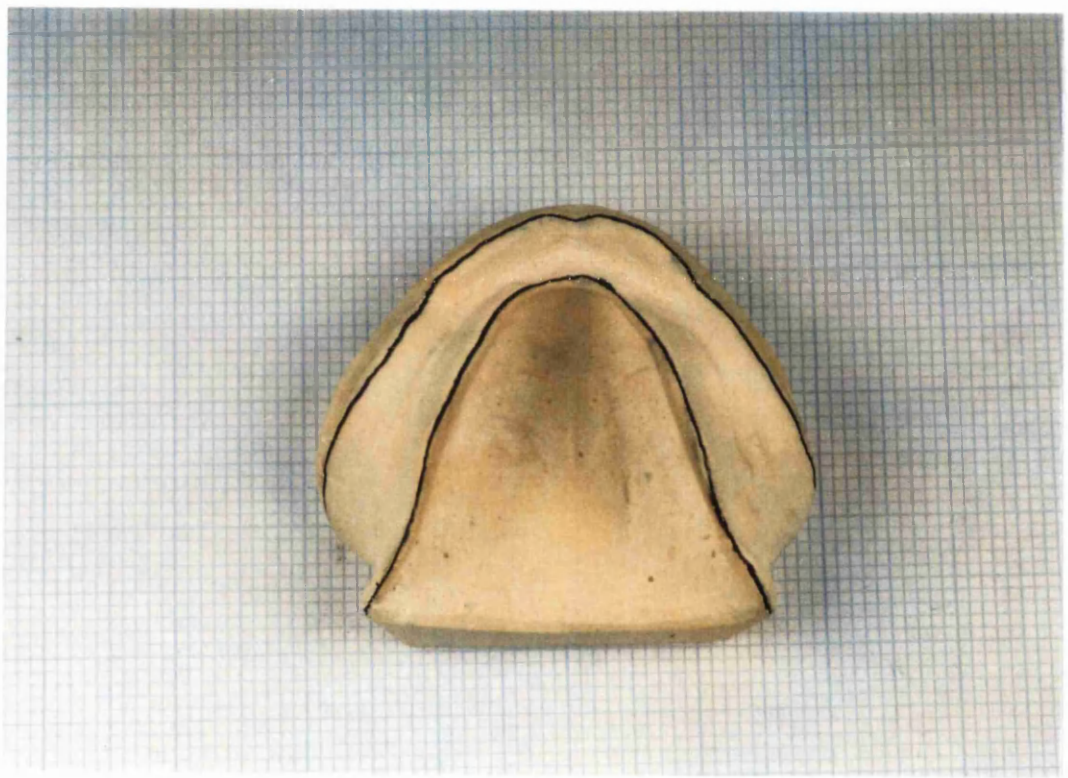

Fig.4.8: Lower cast with an outlined denture bearing area.

Casting wax was adapted to the fitting surface of the cast around the denture bearing area **(Fig 4.9) and,** under a magnifying lens, was trimmed and transferred to graph paper. The outline of the wax transfer was marked on the graph paper **(Fig 4.10)** and under a magnifying lens the squares (one mm ^{2}) were counted to calculate the total surface area.

Fig.4.9: Casting wax adapted closely to the outlined denture bearing area

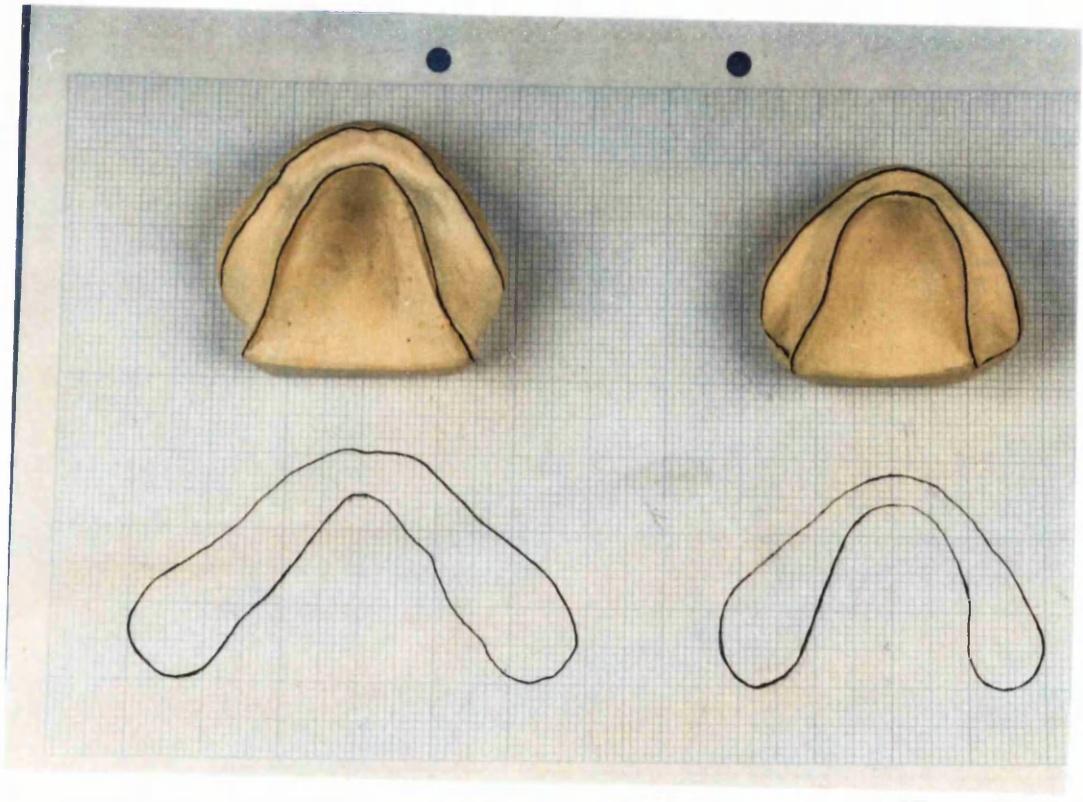

Fig.4.10: The wax transferred onto graph paper and the margin outlined

4.8 RESULTS

4.8.1 Transducer calibration

Calibration of the bite force transducer was carried out on three occasions; before starting the study, midway through measurements and after completion of the study. Results are plotted as dead weights (5, 10, 15, 20 and 25) in kilograms versus displayed output in kgs **(Fig 4.11 a,b,c)**, and the linearity of the transducer with the application of dead weights was confirmed.

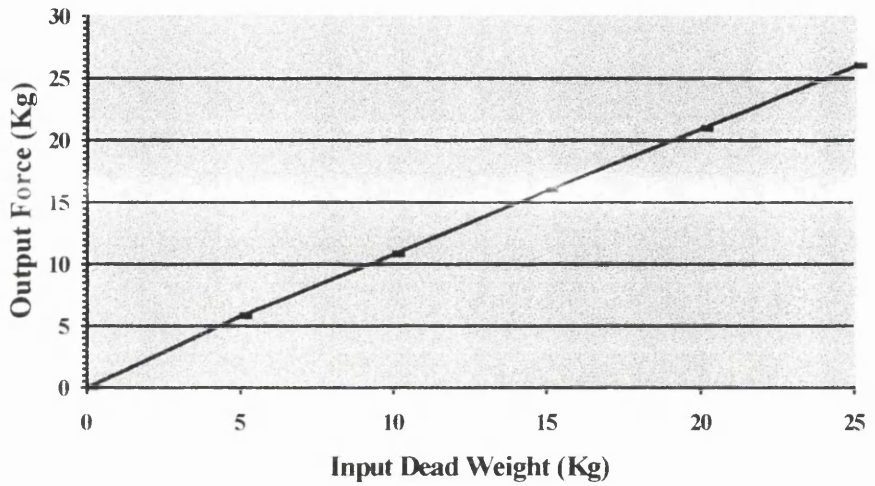

Fig 4.11 a : Pre-treatment calibration of the transducer

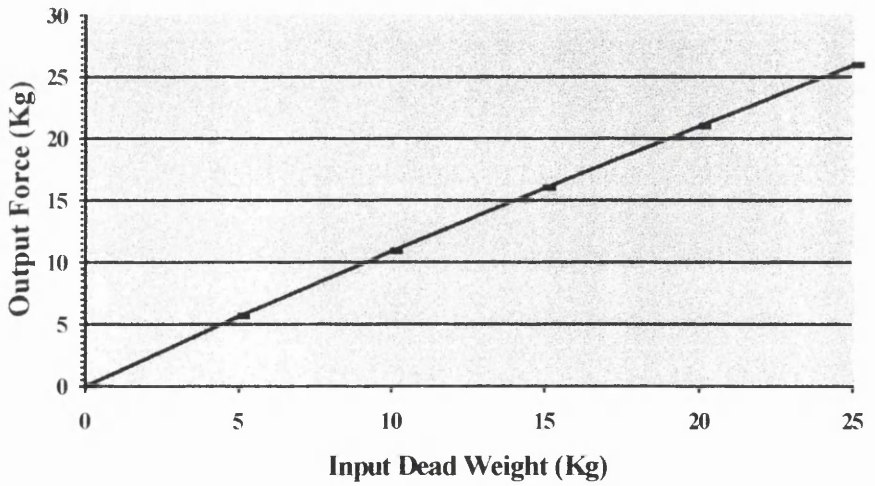

Fig.4.11 b: Mid-point calibration of the transducer

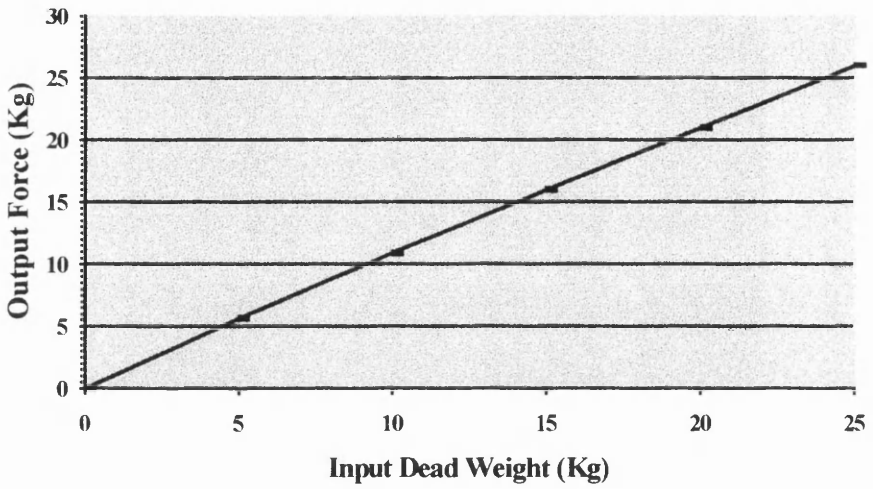

Fig.4.11 c: Post-treatment calibration of the transducer

4.8.2 Measuring of maximum occlusal bite force

In this study the conventional dentures with optimised design were modified by the addition of gold matrix attachments to engage titanium stud attachments on the implant fixtures. Thus the only change in design was implant anchorage of the mandibular dentures after implant placement. Measurement of maximum bilateral occlusal force was undertaken three months after the patients started wearing new conventional complete dentures and was repeated two months after the conversion to implant-retained overdentures. For each patient six repetitive recordings at maximal biting force were made at one session. The maximum occlusal force values for each patient during six recordings are presented in **Table 4.2 to 4.11**, measured values are presented in Newtons (1kg = 9.8 N).

Patient 1

Maximum bite force values for **Patient 1**, before and after implant treatment are shown in **Table 4.2**.

No. of recording	1st	2nd	3rd	**4th**	5th	6th	**Mean**	S.D
MOF (CD)†	170.5	184.2	203.8	**210.7**	197.9	189.1	**192.7**	14.51
MOF (OVD)‡	173.4	184.2	196.0	**233.2**	216.5	194	**199.5**	21.83

Table 4.2: Patient 1, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡**OVD**, Implant-retained mandibular overdenture.

Prior to implant treatment the highest bite force generated, reached at the fourth recording, was 210.7 N. There was a gradual increase in bite force values up to the fourth recording and a decrease after it. The sixth bite force value was higher than the value at the first recording. The use of the implant-retained overdenture showed the same pattern of increasing and decreasing in bite force values, with a highest bite force generated at the fourth recording (233.2 N). The mean values of maximum occlusal force showed a slightly higher mean value for the implant-retained overdenture of 199.5 N compared to the mean value of 192.7 N before implant treatment.

Patient 2

Maximum bite force values for **Patient 2**, before and after implant treatment are shown in **Table 4.3.**

No. of recording	1st	2nd	3rd	**4th**	5th	6th	**Mean**	S.D
MOF (CD)†	158.7	164.6	181.3	**200.9**	188.1	169.5	**177.1**	15.88
MOF (OVD)‡	171.5	174.4	191.1	**217.5**	194.0	182.2	**188.4**	16.77

Table 4.3: Patient 2, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡**OVD**, Implant-retained mandibular overdenture.

Prior to implant treatment the highest bite force generated, reached at the fourth recording, was 200.9 N. There was a gradual increase in biting force generated up to the fourth recording and a decrease after it. The bite force value of the sixth recording was higher than

the value at the first recording. The use of the implant-retained overdenture exhibited a similar pattern of increasing and decreasing in bite force values with the highest bite force value of 217.5 N recorded at the fourth measurement. The mean value of maximum occlusal force was higher at 188.4 N for the implant-retained overdenture, compared with the mean value of 177.1 N before implant treatment.

Patient 3

Maximum bite force values for **Patient 3**, before and after implant treatment are shown in **Table 4.4.**

No. of recording	1st	2nd	3rd	4th	5th	6th	Mean	S.D
MOF (CD)†	147.0	172.4	176.4	**184.2**	158.7	154.8	**165.5**	14.28
MOF (OVD)‡	156.8	171.5	182.2	**203.8**	189.0	181.3	**180.7**	15.88

Table 4.4: Patient 3, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡**OVD**, Implant-retained mandibular overdenture.

Before implant treatment the highest bite force value, reached at the fourth recording, was 184.2 N, with a gradual increase up to the fourth recording and a decrease after it. The sixth recording was higher than the first recording. There was a similar pattern of increasing and decreasing in bite force values with the implant-retained overdenture, with the highest bite force value of 203.8 N recorded at the fourth measurement. The mean values of maximum occlusal force showed higher mean values of 180.7 N for the implant-retained overdenture compared to the mean value of 165.5 N before implant treatment.

Patient 4

Maximum bite force values for **Patient 4**, before and after implant treatment are shown in **Table 4.5.**

No. of recording	1st	2nd	3rd	4th	5th	6th	Mean	S.D
MOF (CD)†	112.7	130.3	162.6	**181.3**	171.5	154.8	**152.2**	26.2
MOF (OVD)‡	100.5	140.5	164.6	**196.0**	185.3	168.6	**159.2**	34.5

Table 4.5: Patient 4, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡**OVD**, Implant-retained mandibular overdenture.

Before implant treatment the highest bite force value, reached at the fourth recording, was 181.3 N. There was a gradual increase in the bite force up to the fourth recording and a decrease after it. The bite force value at the sixth recording was higher than the value at the first recording. The use of the implant-retained overdenture gave a similar pattern of increasing and decreasing bite force values, with the highest bite force value of 196 N recorded at the fourth measurement. The mean value of maximum occlusal force showed a slight higher mean values of 159.2 N for the implant-retained overdenture compared to the mean value of 152.2 N for the optimised conventional denture before implant treatment.

Patient 5

Maximum bite force values for **Patient 5**, before and after implant treatment are shown in **Table 4.6.**

No. of recording	1st	2nd	3rd	**4th**	5th	6th	**Mean**	S.D
MOF (CD)†	128.3	134.2	161.7	**176.4**	167.5	138.1	**151.0**	19.98
MOF (OVD)‡	142.1	145.0	156.8	**194.0**	168.5	145	**158.5**	19.98

Table 4.6: Patient 5, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡**OVD**, Implant-retained mandibular overdenture.

Prior to implant treatment the highest bite force value, reached at the fourth recording, was 176.4 N. There was a gradual increase in the bite force values up to the fourth recording and a decrease after it. The bite force value of the sixth recording was higher than the value at the first recording. The use of the implant-retained overdenture gave a similar pattern of increasing and decreasing bite force values, with the highest bite force value of 194 N recorded at the fourth measurement. Maximum occlusal force showed higher mean value of 158.5 N for the implant-retained overdenture, compared to the mean value of 151 N before implant treatment.

Patient 6

The levels of maximum bite force values for **Patient 6**, before and after implant treatment are shown in **Table 4.7.**

No. of recording	1st	2nd	3rd	**4th**	5th	6th	**Mean**	S.D
MOF (CD)†	86.2	99.9	105.8	**112.7**	99.9	92.1	**99.4**	9.44
MOF (OVD)‡	98.9	105.8	117.7	**142.1**	129.3	99.9	**115.5**	17.41

Table 4.7: Patient 6, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡ **OVD**, Implant-retained mandibular overdenture.

Prior to implant treatment the highest bite force value, reached at the fourth recording, was 112.7 N, with a gradual increase in the bite force up to the fourth recording and a decrease after it. The bite force recorded at the sixth recording was higher than the value at the first recording. The use of the implant-retained overdenture gave a similar pattern of increasing and decreasing in bite force values, with the highest bite force value of 142.1 N recorded at the fourth measurement. The mean values of maximum occlusal force were higher at 115.5 N for the implant-retained overdenture compared to the mean value of 99.4 N before implant treatment.

Patient 7

The levels of maximum bite force values for **Patient 7**, before and after implant treatment are shown in **Table 4.8.**

No. of recording	1st	2nd	3rd	**4th**	5th	6th	**Mean**	S.D
MOF (CD)†	75.4	79.3	86.2	**96.0**	81.3	76.4	**82.4**	7.66
MOF (OVD‡)	83.3	90.1	100.9	**123.4**	115.6	96.0	**101.5**	15.30

Table 4.8: Patient 7, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡ **OVD**, Implant-retained mandibular overdenture.

Prior to implant treatment the highest bite force value reached at the fourth recording, was 96 N with a gradual increase in the bite force up to the fourth recording and a decrease after it. The bite force value of the sixth recording was higher than the value at the first recording. The implant-retained overdenture gave a similar pattern of increasing and decreasing values with the highest bite force value of 123.4 N recorded at the fourth measurement. Maximum occlusal force showed higher mean value of 101.5 N for the implant-retained overdenture compared to the mean value of 82.4 N for the optimised conventional complete denture.

Patient 8

Maximum bite force values for **Patient 8**, before and after implant treatment are shown in **Table 4.9.**

No. of recording	1st	2nd	**3rd**	4th	5th	6th	**Mean**	S.D
MOF (CD)†	66.6	80.3	**93.1**	77.4	71.5	73.5	**77.0**	9.17
MOF (OVD)‡	80.2	90.1	**106.9**	98.9	89.1	86.3	**91.4**	11.44

Table 4.9: Patient 8, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡**OVD**, Implant-retained mandibular overdenture.

Prior to implant treatment the highest bite force value, reached at the third recording, was 93.1 N with a gradual increase in the bite force up to the third recording and a decrease after it. The bite force value of the sixth recording was slightly higher than the value at the first recording. The implant-retained overdenture gave a similar pattern of increasing and decreasing values with the highest bite force value of 106.9 N also recorded at the third measurement. Maximum occlusal force showed higher mean values of 91.4 N for the implant-retained overdenture compared to the mean value of 77 N before implant treatment.

Patient 9

The levels of maximum bite force values for **Patient 9**, before and after implant treatment are shown in **Table 4.10**.

No. of recording	1st	2nd	**3rd**	4th	5th	6th	**Mean**	S.D
MOF (CD)†	72.5	84.2	**95.0**	84.2	80.3	79.3	**82.5**	7.44
MOF (OVD)‡	80.3	93.1	**117.6**	92.1	90.1	84.2	**92.9**	13.06

Table 4.10: Patient 8, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡**OVD**, Implant-retained mandibular overdenture.

Prior to implant treatment the highest bite force value, reached at the third recording, was 95 N with a gradual increase in the bite force up to the third recording and a decrease after

it. The bite force value of the sixth recording was slightly higher than the value at the first recording. The use of implant-retained overdenture exhibited a similar pattern of increasing and decreasing in bite force values with the highest bite force value of 117.6 N recorded at the third measurement. Maximum occlusal force showed a slight higher mean value of 92.9 N for the implant-retained overdenture compared to the mean value of 82.5 N before implant treatment.

Patient 10

Maximum bite force values for **Patient 10**, before and after implant treatment are shown in **Table 4.11.**

No. of recording	1st	2nd	**3rd**	4th	5th	6th	**Mean**	S.D
MOF (CD)†	52.9	56.8	**70.6**	65.8	62.9	55.6	**60.7**	6.37
MOF (OVD)‡	72.5	97.0	**109.7**	99.9	91.1	80.3	**91.7**	13.55

Table 4.11: Patient 10, maximum bite force values (Newtons).
†**CD**, Conventional mandibular denture.
‡**OVD**, Implant-retained mandibular overdenture.

Before implant treatment the highest bite force value, 70.6 N was reached at the third recording. There was a gradual increase in the bite force values up to the third recording and a decrease after it. The bite force value at the sixth recording was higher than the value at the first recording. With the use of the implant-retained overdenture there was a similar pattern of increasing and decreasing values with the highest value of 109.7 N recorded at the third measurement. The mean maximum occlusal force showed value of 91.7 N for the implant-retained overdenture compared to the mean value of 60.7 N for the optimised conventional denture.

4.8.3 Summary

The maximum occlusal force values described for the group as a whole had a similar pattern in all patients irrespective of whether measurements were carried out before or after implant treatment. The highest bite force value was recorded at the fourth measurement for seven patients and at the third measurement for the other three patients. The pattern was exactly replicated for each of the ten patients with both the conventional denture and the

implant-retained overdenture. There was gradual increase in maximum occlusal force values to reach the highest value at the third or fourth recording with a subsequent decrease in all patients with both types of denture. The use of an implant-retained overdenture gave an increase in MOF values compared to those found with the pre-treatment conventional denture, with all patients. The overall values for maximum bite force levels for all ten patients before and after implant treatment are shown in **Table 4.12**.

Patient No.	*MOF/CD†	Mean	MOF/OVD‡	Mean	Difference
1	210.7 N	192.7 N	233.2 N	199.2 N	22.5 N
2	200.9 N	177.1 N	217.5 N	188.4 N	16.6 N
3	184.2 N	165.5 N	203.8 N	180.7 N	19.6 N
4	181.3 N	152.2 N	196.0 N	159.2 N	14.7 N
5	176.4 N	151.0 N	194.0 N	158.5 N	17.6 N
6	112.7 N	99.4 N	142.1 N	115.6 N	29.4 N
7	96.0 N	82.4 N	123.4 N	101.5 N	27.4 N
8	93.1 N	77.0 N	106.9 N	91.4 N	13.8 N
9	95.0 N	82.5 N	117.6 N	92.9 N	22.6 N
10	70.6 N	60.7 N	109.7 N	91.7 N	39 N
Mean	**142 N**	-	**165 N**	-	-

Table 4.12: Maximum occlusal force values, means and differences in the MOF with conventional and implant-retained overdentures.
* **MOF**, Maximum occlusal force.
† **CD**, Conventional complete denture.
‡ **OVD**, Implant-retained mandibular overdenture.

4.8.4 Statistical analysis

4.8.4.1 Statistical tests used

The paired t-test is advocated when the number of the observations is small and there is more than one variable. The main aim of this study was to compare the effects of two alternative treatments in edentulous patients. Maximum bite force was measured for each patient first with conventional complete dentures then after the mandibular denture had been converted to an implant-retained overdenture. Each patient, having received both treatment options, acted as her own control. The paired t-test was used to evaluate the measurements from each subject for each treatment episode, in order to determine the statistical significance. The test was carried out at 95% confidence interval level ($P \leq 0.05$).

A correlation analysis was carried out to check any direct relation between the extent of the

lower denture bearing area (DBA) and the level of maximum occlusal bite force. The correlation coefficient is a measure of the relationship between numerical variables for paired observations. The correlation coefficient (r) ranges from -1, which indicates a negative linear relationship, to +1, which indicates a positive linear relationship. If the correlation coefficient is zero, this indicates that there is no linear relationship between the variables.

4.8.5 Comparison of maximum bite force before and after implant treatment

Comparison of the bite force values before and after implant treatment was performed using both the mean and the maximum occlusal force values, analysed using the paired t-test. Results from both data sets showed there was a highly significant difference between the biting force generated before implant treatment and bite force after implant treatment. This highly significant difference was obtained when both maximum **(Fig.4.12)** and mean **(Fig.4.13)** bite force values were considered with a P values of 0.000 and 0.005 respectively.

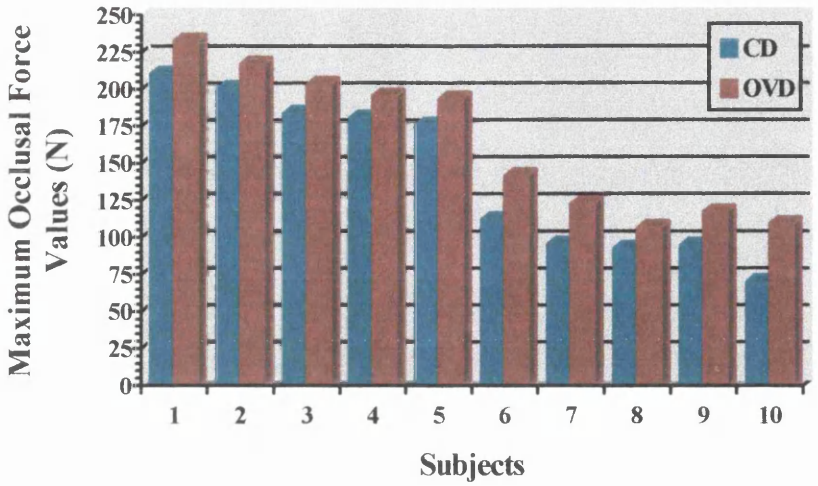

Fig 4.12: The maximum occlusal force values before and after implant treatment.

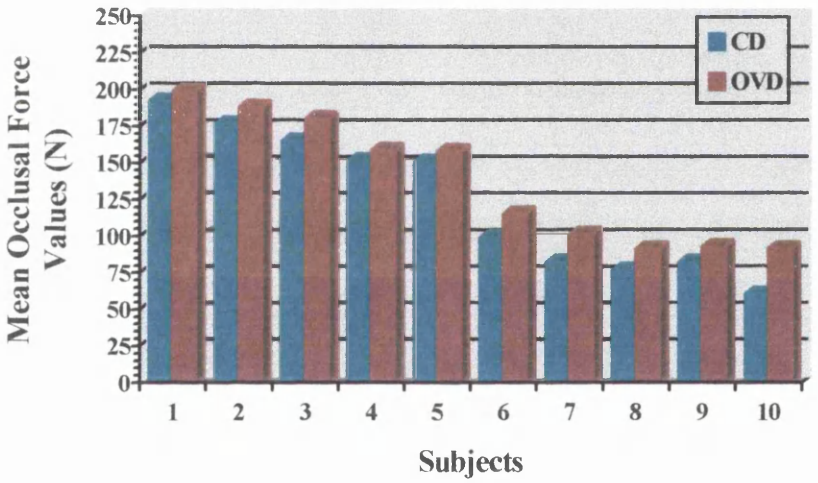

Fig.4.13: Mean maximum occlusal force values before and after implant treatment.

4.8.6 Measuring the denture bearing area.

An early casual observation during the bite force measurement procedures was that those patients with well formed mandibular alveolar ridges appeared to produce the highest maximum occlusal force values. Accordingly, investigation was undertaken to find out if there was any correlation between the recorded maximum occlusal force and the dimensions of the mandibular denture bearing area. The dimensions of the mandibular denture bearing area were measured **(Fig.4.14)** as previously described **(4.8.5)** and the results are shown in **Table 4.13**.

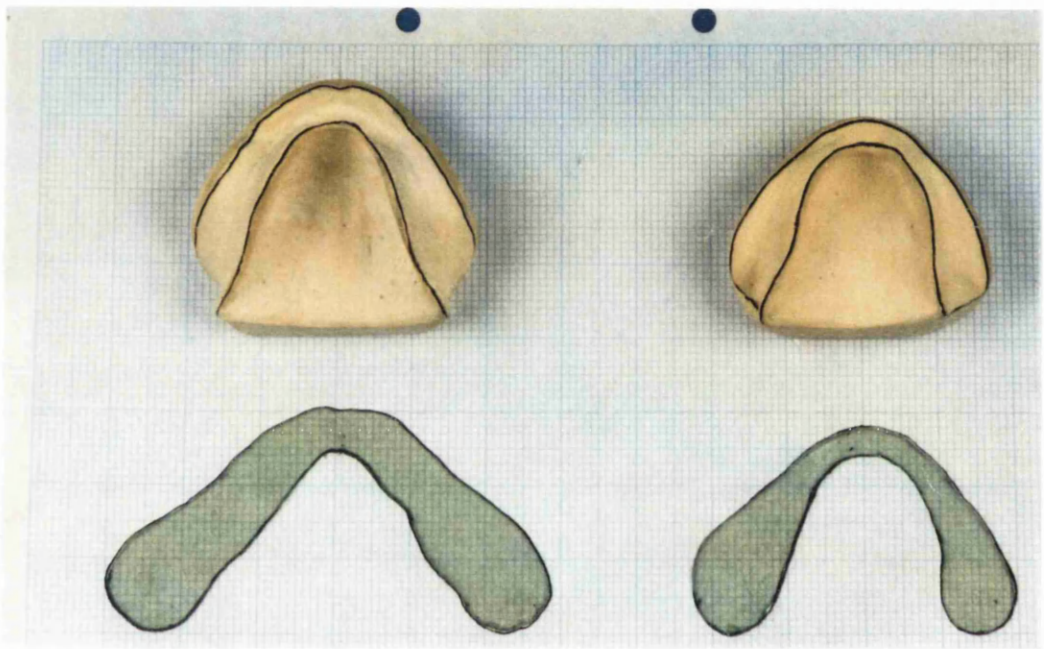

Fig 4.14: Largest denture bearing area patient (No.1) "left" and lowest patient (No.10) "right".

Patient No.	*MOF/CD	**MOF/OVD	***DBA (mm^2)
1	210.7 N	233.2 N	1182
2	200.9 N	217.5 N	1152
3	184.2 N	203.8 N	1120
4	181.3 N	196.0 N	986
5	176.4 N	194.0 N	980
6	112.7 N	142.1 N	914
7	96.0 N	123.4 N	896
8	93.1 N	106.9 N	890
9	95.0 N	117.6 N	646
10	70.6 N	109.7 N	636

Table 4.13: Maximum occlusal force values and denture bearing area.
* **MOF/CD**, Maximum occlusal force values with conventional denture.
** **MOF/OVD**, Maximum occlusal force values with implant-retained overdenture.
*** **DBA (mm^2)**, Lower denture bearing area.

The Pearson correlation coefficient (r) was calculated and there was found to be a highly positive correlation between the mandibular denture bearing area and the MOF values prior to implant treatment, with the Pearson correlation coefficient (r) highly significant (p=0.000) at r=0.894. Following implant treatment, there was a close correlation between the lower denture bearing area on MOF with a Pearson correlation coefficient (r) equal to 0.885 (p=0.001). The correlation between maximum occlusal force values and the measured mandibular denture bearing areas is shown in **Fig.4.15.**

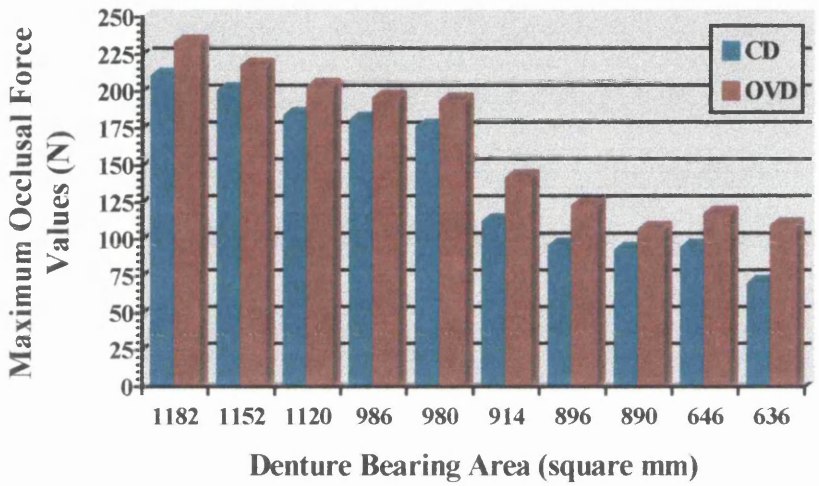

Fig 4.15: Maximum occlusal force values (optimised conventional dentures and implant - retained overdentures) and the lower denture bearing area.

4.8.7 Number of year of edentulism

The length of edentulism in this group of patients ranged from 4 to 35 years. The findings seemed to suggest that the highest maximum occlusal force values were obtained from those patients who had been edentulous for longest periods of time. Accordingly, the Pearson correlation coefficient was calculated to indicate the level of correlation between bite force and number of years of denture wearing. There was only a weak relationship between the level of maximum occlusal force before implant treatment and the length of edentulism (r =0.455), and the correlation after implant treatment was also weak (r=0.491) **[Table 4.14, Fig.4.16].**

Patient No.	Edentulism (years)	*MOF/CD	**MOF/OVD
1	35	210.7 N	233.2 N
2	33	200.9 N	217.5 N
3	20	184.2 N	203.8 N
4	25	181.3 N	196.0 N
5	22	176.4 N	194.0 N
6	20	112.7 N	142.1 N
7	14	96.0 N	123.4 N
8	8	93.1 N	106.9 N
9	4	95.0 N	117.6 N
10	14	70.6 N	109.7 N

Table 4.14: Maximum occlusal force values and number of years of edentulism.
* **MOF/CD**, Maximum occlusal force values with conventional denture.
** **MOF/OVD**, Maximum occlusal force values with implant-retained overdenture.

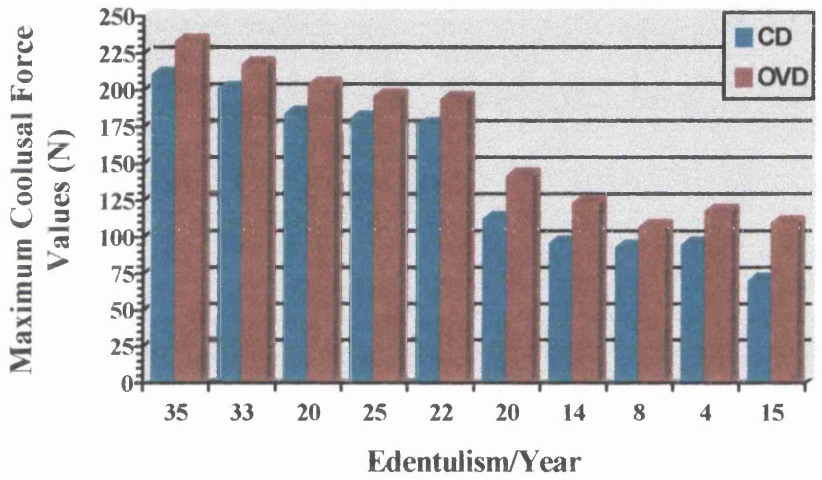

Fig.4.16: Maximum occlusal force values and the number of years of edentulism

4.9 DISCUSSION

In this study a calibrated bite force transducer was constructed and used to measure bilateral maximum occlusal force. The main aim of the study was to measure the maximum occlusal forces generated by edentulous subjects wearing conventional complete dentures, followed by measurement following implant placement and modification of the mandibular dentures, which were retained by two ball attachments.

The bite force transducer proved to be accurate and linear when tested on three occasions; pre-investigation, midway through the study and after the completion of the investigation. The transducer was constructed with a vertical jaw separation of 10-12 mm, in accordance with the suggested opening dimension of 9 to 20 mm during maximum occlusal force measurement reported by Manns et al (1979) and MacKenna & Turker (1978)

In this study, prior to implant treatment, the maximum occlusal force values for the group with the new optimised complete dentures ranged from 70.6.6 N to 210.7 N, with a mean value of 142 N. These results are in a range corresponding to the maximum occlusal force values described by Haraldson et al, (1979a); Ralph, (1979); Meng & Rugh, (1983) and Coaizzi et al, (1984) who reported maximum occlusal force values ranging from 77 to 196 N in subjects wearing complete dentures. It is of course, the case that variation owing to differences in the age, sex and background of the sample population would be expected.

After implant treatment, the maximum occlusal force values ranged from 109.7 N to 233.2 N, with a mean value of 165 N. Thus there was a trend to increased bite force values after implant treatment. Because of methodological differences and the varied conditions in which different studies have been undertaken, it is often difficult to make reliable comparisons between the results reported by different workers with respect to maximum occlusal force values. Nevertheless, the findings of the present study are in broad agreement with those of Haraldson et al (1988) and Meriscke-Stern et al (1993) and Meriscke-Stern & Zarb (1996). The slight increase in MOF values after implant treatment in the present study in comparison with studies of Haraldson et al (1988) and Meriscke-Stern et al (1993) may be due to the stability of both dentures during the measuring

procedure. This was carried out using a biting template to give a reproducible jaw position each time measurement was undertaken. In the studies of Haraldson et al (1988), Meriscke-Stern et al (1993) and Meriscke-Stern & Zarb (1996) MOF values were measured unilaterally, and the stability of dentures may have been compromised by unilateral measurement, despite the use of a cotton roll in the opposite side. In addition they carried out the measurement in a pair of antagonist denture teeth, whereas in the present study measurement was carried out over a group of teeth. Falk et al (1989) asserted the importance of denture stability during maximum occlusal force measurement and Pruim (1979) and Bakke et al (1990) reported that unilateral measurement of bite force has been found to produce approximately 50% of the values obtained with bilateral measurement in subjects with natural dentition.

In the present study the highest levels of improvement in maximum occlusal force values occurred in those patients with the lowest initial bite force prior to implant treatment. The increases ranged from 13.8 to 39 N, conversion of the prostheses to implant-retained overdentures following placement of two mandibular implant fixtures consistently improved this aspect of masticatory function.

The results of this study showed a progressive increase in the bite force developed during successive clenching episodes, followed by a gradual decrease after either the third or the fourth recordings. This was observed in all subjects, both before and after implant treatment. This appears to be a good indicator that the mandibular denture remains tissue-borne, even after implant treatment, with clenched loads still transmitted to the supporting mucosa. It is likely that the sensation of pressure on the mucosa made the patients slightly tentative when applying loads, building up to a comfortable level. Most of the subjects in the study reported a feeling of discomfort after the recording sessions due to fatigue of the jaw closing muscles. This would account for the reduction in the MOF values in the final clenches of the sessions. A similar finding has been reported by Van Steenberghe & De Vries (1978) in dentate subjects who showed a gradual decrease in bite force values after the sixth repetitive clench.

It is of interest that the maximum occlusal force values found in the present study appeared to have a linear correlation with the denture bearing area in nine patients out of ten. While other examples of this particular finding were not found in the literature, Lindquist et al (1986) found that the highest maximum occlusal force values were reported in edentulous patients with the least mandibular ridge resorption, where the degree of mandibular ridge resorption was estimated by the use of radiographs. However this finding with respect to the denture bearing area should be interpreted with caution, owing to the simple manual method used in calculating the denture-bearing surface area. The patient who showed the smallest increase in MOF value following implant treatment (patient No.8) experienced moderate pain at the sites of the tempromandibular joints at the time of evaluation. Clinical examination revealed slight tenderness and clicking from both joints. These CMD symptoms may have been a factor in the marginal increase in bite force, despite a relatively large denture bearing area. This is in agreement with some studies reporting that subjects with CMD symptoms, such as pain from the masticatory muscles or from the tempromandibular joints, generated a lower occlusal force values than healthy subjects (Molin, 1972; Helkimo et al, 1975).

It appeared from the study that the longer patients were edentulous, the more was the increase in the maximum occlusal force value after implant treatment, although there was no significant statistical correlation between these two factors. This result may be explained as being owing to "overadaptation". As patients adapt to wearing dentures their tolerance seems to increase with time and improved neuromuscular control may develop (Weinstein et al, 1988). Patients with more denture experience may have the ability to learn to control a new denture more quickly than patients with less dentures wearing experience. This view has been expressed by Ettinger (1971) and Sheppard et al (1972). On the other hand, Carr & Laney (1987) found the longer patients were edentulous, the smaller were the increases in the MOF values following implant treatment.

4.10 CONCLUSIONS

In conclusion, ten subjects treated using two implant fixtures to retain a mandibular overdenture showed an improvement in denture stability which was reflected by a substantial improvement in masticatory functions as recorded by an increase in maximum occlusal values.

In this study a high degree of accuracy and consistency was demonstrated from the use of the bite force transducer with a controlled method of bite force measurement. After implant placement there was a uniform increase in maximum bite forces generated.

It was also concluded that there may be a direct relationship between bite force generation and the lower denture bearing area. All these observations request further investigation.

CHAPTER FIVE

THE INFLUENCE OF CONVENTIONAL COMPLETE DENTURES AND IMPLANT-RETAINED OVERDENTURES ON SPEECH.

5.1 GENERAL INTRODUCTION AND REVIEW OF LITERATURE

The neurophysiological mechanisms of speech are complex, with a number of oral mechanoreceptors involved in its motor control (Karlsson & Carlsson, 1993). The speech mechanism involves mainly the upper digestive and respiratory tracts, with the use of three physiological valves. The first valve, the true vocal fold of the larynx (glottis), functions only with speech sounds that have a laryngeal tone as in voiced sounds such as /B/, /A/ and /N/. In the production of these sounds the glottis is closed and the vocal cords are subjected to varying degrees of tension such that they vibrate upwards. Otherwise, the exhaled air stream passes through the region without any disturbance as is the case in voiceless sounds such as /P/, /T/ and /S/. The second valve in the palatopharyngeal region is affected mainly by the functional movement of the soft palate in relation to the pharynx to control air movement between the oral and nasal airway. The mouth, the third valve, is particularly complicated due to its capability of changing size and shape. These valves act as generators of sounds which enable the individual to speak and communicate (Martone & Black, 1962 a,b).

Articulation is the process of obstruction or shaping the stream of exhaled air to produce sequences of sound that make up the spoken language. Speech sounds have an aerodynamic characteristic, in the sense that the airflow and the changes in air pressure occur in a chamber that is adjustable. When exhaled air passes from the lungs through the trachea, sound is produced by vibration of the vocal cords during exhalation. The tongue plays a major role in the mechanism of speech by changing its shape and position of contact with the static structures, such as the teeth, the alveolar processes and the hard and soft palates, to form the speech sounds. The oral cavity, nasal cavity and the air sinuses, act as resonance chambers where the sound waves are modified, and the diaphragm and the intercostal muscles control the

volume and rate of flow of the air stream. Congenital defects or acquired disease producing malfunction of these structures can result in a lack of balance between the oral and nasal cavities and distortion of sound quality (Morley, 1957; Chierici et al, 1978; Palmer, 1974; Sommorlad et al, 1994). Moreover, a loss of nasal resonance may occur when the nose is obstructed temporarily by a common cold, or permanently by adenoid growth (Bond & Lawson, 1968).

Turbulence influence sound, as when the obstructed airflow is forced by the tongue through a narrow groove to produce fricative sounds such as /S/ and /SH/. The plosive sounds are produced when the exhaled air is impounded behind the lips or the tongue as it moves to the palate. The air pressure increases behind this dam created by the tongue when it acts against the teeth or the palate, and air is suddenly released to create this characteristic noise in sounds such as /B/, /D/, /G/, /P/, /T/ and /K/. The affricative sounds are usually produced when the damming of the air increases the intra-oral air pressure giving a fricative and plosive like noise such as /CH/ (Palmer, 1974).

Speech defects can be developmental or acquired, and many factors such as mental deficiency, deafness, abnormalities of the speech organs, emotional factors, lack of stimulation from the surrounding environment and neuromuscular disorders may contribute to speech defects. Dental factors which may be of importance include malocclusion or the wearing of complete dentures, if the individual is unable to compensate for changes in the oral cavity (Bond & Lawson, 1968; Palmer, 1974). The detrimental effects of complete dentures on speech are likely to arise due to the improper positioning of the artificial teeth in the labio-lingual and bucco-palatal direction or a palatal configuration which restricts the natural movement of the articulatory elements such as the tongue and the lips (Rothman, 1961; Lawson & Bond, 1968; Murray, 1978; Palmer, 1974,1979; Goyal & Greenstein, 1982; Kanayama & Mizokami, 1993).

5.1.1 TYPES OF SOUNDS

Vowel sounds /A/, /E/, /I/, /O/, /U/ are produced by a continuous stream of exhaled air passing through the oral cavity without any interference. All the vowels involve the use of the tongue in relation to the soft and hard palates to determine the quality of the sound. Consonant sounds are normally produced by the air stream being obstructed in its passage through the oral cavity by complete or partial seals by the tongue against teeth or the palate or by closure of the lips. These consonant sounds may be classify into bilabial, labiodental, dental , linguopalatal and nasal sounds (Mitchell & Grant, 1976).

Bilabial sounds are formed by the lips and include the /B/, /P/ and /M/. The sounds /P/ and /B/ are articulated by the lips which are suddenly parted allowing an air stream to escape through the mouth. These are plosive sounds. The /M/ sound is articulated by both lips, but air is allowed to escape through the nose. Labiodental sounds such as such as /F/ and /V/ are formed with the lips and teeth in contact, and dental sounds such as /TH/ is formed with the tongue in contact with the teeth. Linguopalatal sounds are formed by the tongue in contact with the palate. These sounds will vary depending on whether tongue contact is made with the anterior part of the hard palate (e.g. /D/, /T/, /S/, /Z/, /R/), the posterior part of the hard palate (e.g. /J/, /CH/, /SH/) or the soft palate (e.g. /J/, /K/, /G/, /NG/). Nasal sound are produced when the air flow is directed completely through the nasal cavity. To produce these sounds (e.g. /M/, /N/, /NG/) the soft palate is pressed downwards and forwards.

It is evident from the literature that the fricative consonant sounds (e.g. /F/, /V/, /S/, /Z/, /SH/, /DH/, /ZH/, /TH/) are most frequently the defective sounds in the case of malocclusion and in patients wearing orthodontic appliances or complete dentures (Lawson & Bond, 1969; Palmer, 1974,1979; Tobey & Finger, 1983). The vowel sounds are affected to a lesser degree by dental prostheses, because in the production of vowels there is no contact between the tongue and the upper anterior teeth or the alveolar ridge and the palate. Thus, the insertion of a denture in the mouth will not influence the production of these sounds, although it might affect their resonant quality (Mitchell & Grant, 1976).

5.1.2 SPEECH ARTICULATION

The air stream which passes through the vocal cords to the larynx and into the oral and nasal cavities cannot be termed "speech" unless it is formed into the meaningful elements of speech by movements of the articulatory structures, i.e. soft palate, mandible, tongue and lips. This process is termed speech articulation. It is evident that the articulatory mechanisms are the most important elements for the production of speech sounds and without the ability of articulation, the sounds would be inadequate (Petrovic, 1974; Palmer, 1974; Mitchell & Grant, 1976).

According to Palmer (1974) problems of speech associated with dental prostheses are generally articulatory, and articulatory defects may classified into omissions, substitutions and distortions. Children in developing speech skills, will often show omissions when they have failed to learn the sounds. This is common for individuals learning a non-native language, but uncommon among people who wear dentures (Mitchell & Grant, 1976). On the other hand, substitutions (where one sound is replaced by another) may be found in denture-wearing patients. For example, one might hear the patient say /TH/ for /S/, as in "Think" for "Sink". Probably the most common articulatory defect is distortion, sometimes called “whistling”. The term distorted speech is used when a sound is not at all like the intended sound, and might cause difficulty for the listener in understanding the speaker. Distortions are common among the denture wearers, as in "Ink" for "Sink", the /S/ is distorted and the word is unintelligible (Frowine & Moser, 1963; Palmer, 1974,1979; Chierici et al, 1978; Ghi & McGivney, 1979).

5.1.3 CHANGES IN ORAL MORPHOLOGY

As dentures produce a change in oral morphology, patients may tend to change speech articulation following the provision of a denture (Allen, 1958; Troffer & Beder, 1961; Boucher, 1970; Mitchell & Grant, 1976; Murray, 1978; Ritchie & Ariffin, 1982; Tobey & Finger, 1983). Patients tend to compensate by making changes in the method of articulation. However, if patients fail to adapt to new dentures defective speech may be a problem (Bond & Lawson, 1968; Palmer, 1974). The fricative sounds are particularly difficult for denture wearers to compensate for (Bond & Lawson, 1968; Palmer, 1974, 1979).

Chierici et al (1978) carried out an investigation to determine the influence of immediate dentures on speech production. Sixteen subject were included and speech recordings were made before extraction of the patients' teeth and within two weeks after the insertion of immediate dentures. Three words were used for all patients, *cat, soup* and *sick*. It was reported that the /S/ sound was the only sound effected by the transition from natural teeth to an immediate denture.

Speech distortion has been noticed in patients with mandibular atrophy. With progressive bone loss following the extraction of the teeth, the supporting function of orbicularis, mentalis and the depressor labii muscles may be affected when their origins on the alveolar ridge disappear. This can lead to changes in muscle function, resulting in speech defects (Powers & Bosker, 1996). Traditional preprosthetic surgery procedures such as vestibuloplasty and lowering of the floor of the mouth have been used in an attempts to improve denture base stability and retention. However, these procedures have led to further stripping of the muscular attachments on the mandible and can cause deterioration of speech.

It has been reported that rehabilitation in patients with mandibular atrophy by using implant-retained overdentures has resulted in improvement in speech (Maxson et al, 1989; Bosker et al, 1991a). Conversely, full-arch rehabilitation with fixed bridges supported by osseointegrated dental implants, particularly in the upper arch, has frequently resulted in speech problems (Haraldson & Carlsson, 1977; Worthington et al, 1987; Jemt, 1991, 1994; Lundqvist et al. 1992a & b; Lundqvist, 1993), particularly associated with the /S/ and /T/ sounds. This is due to air escape through the inter-implant spaces.

5.1.4 FACTORS INFLUENCING THE SPEECH OF COMPLETE DENTURE WEARERS

5.1.4.1 Vertical dimension

It is generally considered that an excessively increased or decreased vertical dimension interferes with speech articulation and care must be taken while measuring the vertical dimension in edentulous patients due to its possible influence on speech. If the vertical dimension is excessive this will result in an increased oral resonance due to the space created between the tongue and palate. In this case, the tongue must be raised more than usual to achieve a lateral oral seal, it may become fatigued and a lateral escape of air is possible. The patient may have slurred speech due to changing from high to low tongue positions. The patient is likely to complain of muffling or clattering sounds because the mandible will tend to retain it's normal relationship to the maxilla for certain sounds (particularly /S/ sound), but is prevented from doing so because of the fatigue of the masticatory muscles and the teeth contacting before the expected time (Silverman, 1967; Kuebker, 1984; Hammond & Beder, 1984). On the other hand, if the vertical dimension is reduced, the patient will have a reduced oral resonance because of the small space between the tongue and palate (Silverman, 1952; Kaires, 1957; Lawson & Bond, 1969; Sherman, 1970; Pound, 1970).

5.1.4.2 Occlusal plane

The importance of the occlusal plane lies in the production of the labio-dental sounds /F/ and /V/. It has been advocated by Pound (1976) that the occlusal plane is determined by relating the incisal edges of the upper incisors to the lower lip during the articulation of these sounds. If the occlusal plane is too high the lower lip will not easily meet the incisal edge of the upper anterior teeth. If the occlusal plane is too low the lower lip will overlap the labial surface of the upper teeth to more than ideal degree. Therefore both high or low occlusal planes may effect speech and phonation, with either increasing or decreasing oral resonance (Silverman, 1952; Lawson & Bond, 1969; MacGregor, 1989).

5.1.4.3 Antero-posterior position of the anterior teeth

It has been reported that the setting of denture teeth should reproduce the position of their natural successors, to permit a natural tongue space and to help in patients' neuromuscular adaptation. This can be achieved by using pre-extraction records, particularly in patients with a normal jaw relationship (Silverman, 1967; Murray, 1977,1978; MacGregor, 1989). In the absence of natural teeth or pre-extraction records, an indication of the previous tooth position can be obtained with reference to remaining anatomical landmarks such as the incisive papilla, centre of the alveolar ridges and the retero-molar pads (Murray, 1977). According to Murrell (1972), Silverman (1967) and Pound (1976) the phonetic methods for replacing the anterior artificial teeth is a useful functional technique, using the "closest speaking space" and utilising the /S/ sound.

A normal relationship between the upper and lower anterior teeth in appropriate overjet and overbite is important for the pronunciation of most sounds. In the production of vowel sounds the tip of the tongue normally lies in the floor of the mouth, in contact with the lingual surface of the lower anterior teeth. Muffling sounds can occur if the overbite between the anterior teeth is too deep, because the mandible cannot easily be protruded for /S/ and /Z/ sounds, unless the mouth is opened more than usual. This in turn leads the tongue to occupy a more posterior position, resulting in an increase in nasality. If the anterior overbite is reduced a wide space will be produced between the upper and lower incisor teeth, resulting in defective production of the /S/ sound (Lawson & Bond, 1968).

The teeth are the static component of the speech apparatus and serve as the obstruction against which the tongue apex directs the air to create the friction sound, as in "S" sound production when air escapes from median groove of tongue and the tip of the tongue just behind the maxillary incisors teeth. The lateral borders of the tongue are in contact with the palatal surface of the upper posterior teeth and palatal tissue (Rothman, 1961). In 1978, Murray found that in normal or class I jaw relationship two distinct tongue positions were observed for the /S/ sound; the first with the tongue tip against the lingual surface of the lower incisors in 80% of cases, and the second with the tongue tip against the lingual surface of the both upper and lower incisors. Therefore, if the upper anterior teeth are placed too far palatally or

the palatal area of the maxillary denture is too thick or the posterior teeth are kept too far palatally, lisping will occur with the /S/ sound, sometimes called a lateral lisp. Whistling may occur if the upper incisors are situated too far labially or the upper posterior teeth too far buccally. In this situation the tongue is forced to stretch more than usual, creating a narrow aperture. The sound of /S/ will change to /TH/, sometimes called a frontal lisp (Rothman, 1961; Lawson & Bond, 1968; Palmer, 1974; Petrovic, 1974,1985; Ritchie & Ariffin, 1982).

5.1.4.4 Denture thickness and extension

The anterior palatal region in the normal oral cavity has three components which are important in speech production; the incisive papilla, the mucous membrane and the palatal rugae. The mucous membrane contributes a sensory surface which provides biofeedback, along with the tongue and the auditory system, to monitor the articulatory process. With this surface covered by a denture this sensory feedback is reduced, resulting in a decrease in the patient's skill of self-correction. It has been suggested that the denture should be kept as thin as possible, particularly in the palatal surface where the tongue makes contact, and it should be chamfered in the post-dam region to avoid any irritation to the dorsum of the tongue and to avoid interference, especially with the vowel sounds, on speech (Allen, 1958; Palmer, 1979).

One of the most common reasons for speech deterioration in denture wearers is a narrowing of the tongue space, caused by a thickened denture base or improper positioning of the upper and the lower posterior teeth. According to Palmer (1974,1979) air turbulence is of importance in understanding the effect of dentures in speech articulation. Normally the sibilant sounds are produced by turbulence of air across the static or the dynamic speech articulatory elements. As the flow of air through the respiratory tract is directed by the tongue there is a pressure drop across static structures such as the teeth, alveolar ridges and the hard palate. For optimal speech, the tongue must have a proper relationship with the teeth and freedom to assume a postural position and to move in the mouth to create air-flow channels for speech production. The distortion of speech sounds in complete denture patients may arise because of problems with the static or the dynamic speech articulators or with both of them.

5.1.4.5 Denture arch width

Care must be taken to allow adequate space for the tongue. If the posterior teeth are placed too far lingually the tongue may be cramped. With tongue restriction, denture movement and difficulty in speech may occur (Silverman, 1967; Lawson & Bond, 1969; Palmer, 1974; Kanayama & Mizokami, 1993).

5.1.4.6 Lack of retention and stability

A patient's fear of denture dislodgement will result in a cautious attitude towards speech. If denture control is lost, the patient may feel the urge to clench while speaking so as to keep the denture in it's position, resulting in unintelligible and muffled speech, "denture speech" (Lawson & Bond, 1969). Other studies have reported that the use of denture adhesive to improve the retention and stability of maxillary dentures produced an improvement in oral function such as chewing, swallowing and speech activities (Grasso et al, 1994).

5.1.5 SPEECH IN COMPLETE DENTURE WEARERS

Denture patients may complain of speech problems and it would appear from the literature that the fricative sounds, particularly the /S/ sound and its counterpart the /Z/ sound, are most affected by changes in oral morphology (Ylppo, 1955; Bond & Lawson, 1968; Palmer, 1974,1979; Ghi & McGivney, 1979; Ritchie & Ariffin, 1982; Petrovic, 1974,1985; Lundqvist et al, 1992 a & b; Lundqvist, 1993). Care is required when constructing any dental prostheses so as not to interfere with the normal speech. Several studies have reported varying periods for speech adaptation immediately after denture insertion. In some studies patients have returned to normal speech after one to three weeks (Allen, 1958, Boucher, 1970; Tanaka, 1973; Petrovic, 1985), while other patients experience difficulty for one month or more (Troffer & Beder, 1961; Bergman & Carlsson, 1972; Matsuki, 1972; Hamlet and Stone, 1978). It is reported that older patients, provided with new complete dentures, show reduction in speech quality due to delays in the adaptation process (Martone, 1963; Silverman 1978; Hamlet and Stone, 1982).

Patients' emotional attitude towards dentures has been found to be an influential factor on the speech mechanism. Chierici & Lawson (1973) and Palmer (1979) reported that dissatisfaction with denture appearance may inhibit lip, tongue and jaw movements during speech in an effort by the patient to hide the denture. The same effect may occur when dentures are unstable, so the patient hesitates during speech in order to keep the dentures in place. It has been reported that improvement in denture stability results in better speech articulation, where the speech was judged by listening panels (Grasso et al, 1994).

Many methods have been used for assessment and evaluation of speech in edentulous and dentate subjects before and after using a prosthesis, based on the judgements of expert speech therapists or non-expert listeners. It has been found that the validity and reliability of these methods depended on the number of examiners and their professional training (Tanaka, 1973; Hamlet et al, 1978; Ritchie & Ariffin, 1982; Petrovic, 1985).

Angello and Wictorin (1972) studied phonetic changes in edentulous patients at three time intervals following complete denture treatment. Trained speech therapists assessed each patient by the method of "word-paired comparison". Words spoken in the edentulous state were compared with words spoken at different stages of denture wearing. It was found that the /S/, /SH/, /T/ sounds were slightly improved after denture insertion, while the /TH/ sound did not show any improvement in either the therapist judgements or on spectrogram analysis. The overall agreement between the judges was low following the use of dentures.

Many studies have been carried out to investigate the correlation between the quality of speech, denture morphology and the adaptability of the tongue to changes in the intra-oral dimension, by using the spectrogram (Petrovic, 1974,1980,1985; Ritchie & Ariffin, 1982). Allen (1958) looked at a group of dentate individual with normal speech using palatograms showing that no two persons made contact with exactly the same area while pronouncing the consonant sounds. Reproduction of the palatal rugae was noticed to be of importance in pronunciation of /T/, /D/, /N/, and /L/ sounds. Similar findings with respect to replication of the incisive papillae and the rugae on the polished surface of the maxillary denture and their effects in speech improvement have been reported by Palmer (1979). The most sensitive area with respect to speech reproduction was found to be the anterior region of the hard palate, from cuspid to cuspid. An addition of 1 mm of wax in this area made speech difficult and unintelligible, while the addition of the same thickness of wax posteriorly resulted in awkward but clear speech. It is apparent from the literature that in order to produce a proper articulation of speech in complete denture patients, an effective tongue-to-palate contact is an important factor (Allen, 1958; Tanaka, 1973; Palmer, 1974; Desjardins, 1974; Goyal & Greenstein, 1982)

Goyal & Greenstein (1982) investigated the effect of palatal vault shape on speech production in complete denture wearers. Ten edentulous patients were provided with conventional complete dentures and with a second maxillary denture identical other than for a modified palatal contour. At the trial stage the polished surface of the second maxillary denture was roughened with an acrylic bur and painted with impression wax and the patients were asked to read ten sentences containing the

consonant sounds /D/, /J/, /N/, /L/, /S/, /Z/, /T/, /CH/, /SH/ and /ZH/. A positive tongue contact in the wax was identified as a smooth contact and the waxed denture was processed in the normal way. Recording of speech was carried out with the conventional maxillary denture, and with the modified maxillary denture. Speech was judged by a speech pathologist with respect to clarity, intelligibility and articulation and it was reported that there was a significant improvement of speech with the modified denture. Seven of the ten patients showed a preference for the modified denture. These findings are in agreement with those of Tanaka (1973) and Palmer (1974) who used perceptual speech analysis by means of a listening panel, and with those of Allen (1958) and Ritchie & Ariffin (1982) who used acoustic analysis with the use of a spectrogram.

The effect on speech articulation of increasing the occlusal vertical dimension has been investigated by Hammond & Beder (1984) in three groups of patients; dentate subjects, patients with mandibular overdentures retained by natural abutments and complete denture wearers. The occlusal vertical dimension was increased by 4 mm with the use of an acrylic splint covering the mandibular arch. It was reported that the fricative sounds were most affected by the increase in occlusal vertical dimension. The overdenture subjects showed the least misarticulation and the subjects with a natural dentition exhibited the least progression in speech and the slowest adaptation to the acrylic splint. It was suggested that adaptation was influenced by previous adaptive experience, this perhaps being a more significant factor than the proprioceptive input in adaptation to alteration in the vertical dimension. This is supported by the fact that the complete denture subjects, who had no mechanoreceptors due to the loss of the natural teeth but who had a history of wearing prostheses, showed more rapid adaptation to the increase in the occlusal vertical dimension than those subjects with a natural dentition.

Petrovic (1974) indicated that spectrogram analysis contains significant quantitative information about the quality of speech and provides a quantifiable difference between intelligible and unintelligible sounds. He indicated that the spectrogram could be used for objective diagnosis of speech status, especially in complete denture wearers. In 1985 Petrovic conducted a study to investigate the quality of speech

using spectrogram analysis in patients with full dentures of differing morphology, such as differences in palatal thickness and in the position of the upper incisor teeth. Small alterations in the anterio-posterior position of the upper incisor teeth, had a strong influence on the quality of speech production. Movement of the incisor teeth 2 mm labially, using the incisive papillae as a reference position, caused speech distortion in up to 80% of the selected words in relation to the reference speech of the subjects. Furthermore, alterations in the overjet or overbite relationship caused significant changes in the form of the spectrogram analysis. Alterations to speech were apparent when the palatal thickness of the denture was greater than 1.5 mm. It was observed that adaptation depended strongly on the patient's hearing perception capabilities.

Similar findings were reported by Petrovic (1980) and by Ritchie & Ariffin (1982) who suggested that the correct contour of the palate and the positioning of the upper central incisors were important considerations for the production of clear speech sounds. Ritchie & Ariffin (1982) suggested that the spectrogram findings should be confirmed by speech therapists assessing the quality of sounds. It seems clear that factors such as proper tooth position, correct vertical dimension of occlusion, reproducing the incisive papilla and palatal rugae and the provision of adequate tongue space, must be taken into consideration during complete denture construction.

5.1.6 SPEECH IN IMPLANT PATIENTS

It is evident from the few studies on speech production with implant patients that tooth loss and prosthetic treatment may influence aspects of speech performance. Studies of implant prostheses, particularly with complete arch rehabilitation, have shown that many patients had initial speech problems associated mainly with the /S/ and /T/ sounds. This was influenced by the position of the implant fixtures, the space available for the tongue and the width of the interdental spaces (Lundqvist et al, 1992 a & b). The hearing mechanism was found to be an influential factor in speech production. If auditory feedback is impaired patients often find it difficult to adapt the production of speech sounds following changes in the oral cavity (Lundqvist et al, 1992).

In a study of patients treated with implant-supported prostheses it was reported that 53% experienced speech difficulty, mainly during the first few weeks or months after insertion (Jemt, 1991).

Lundqvist et al (1992 a & b) studied a group of patients treated with upper implant-fixed bridges; all patients were subjected to audiological examination and their speech was recorded before and after the treatment. Speech judgements were made by perceptual analysis (experts pathologist and non-experts listener) and acoustic spectrographic analysis, and audiological analysis was carried out. Results revealed that 60% of the patients were judged to have indistinct speech after the transition from complete dentures to fixed prosthesis supported by osseointegrated implants, especially in /S/ sound production. There was no significant correlation between the opened or closed interdental space and the deterioration of speech. It was found that 67% of the patients suffered from hearing defects, as revealed by audiological examination and it was considered that hearing impairment may play an important part in the effort to adjust or to overcome speech difficulties after treatment with maxillary fixed prostheses.

In another study carried out by Lundqvist in 1993, all procedures including the number of patients and the study construction were replicated as in the previous

study (1992), with the additional stage of self-assessment questionnaires, completed by patients to evaluate their own speech before and after the treatment. It was found that 92% of the patients considered themselves to be free from any speech problems at the end of the 3-year follow-up period. The speech pathologists' judgmental analysis revealed that 37% of the complete denture patients had indistinct speech and three months after implant treatment 49% of the patients spoke indistinctly. Three year later, only 31% of patients had a deteriorated speech. The spectrogram analysis pattern for the /S/ sound was normal with similar patterns evident before implant treatment and three years later. Opened or closed interdental space did not appear to influence the incidence of speech defects. Hearing impairments or defects contributed to speech difficulty, specifically in /S/ sound production.

In 1994, Jemt reported that speech problems were the most frequent complaints of patients treated with fixed prostheses supported by osseointegrated dental implant in the edentulous maxilla, particularly during the first year of function. Patients were subjectively evaluated with the use of self-assessment questionnaire and followed-up for five years. This problem has been observed to varying degrees by others when they assessed patients' speech by means of questionnaire (Haraldson & Carlsson, 1977; Worthington et al, 1987, Jemt, 1991) and by objective measures with the use perceptual and acoustic analysis (Lundqvist et al, 1992a & b; Lundqvist, 1993). In all the studies mentioned, speech problems reduced with passing time due to patients' adaptation to the new prostheses. It has been suggested in other studies that the use of a removable labial flange to prevent the air-escape between the alveolar ridge and the fixed prosthesis may help produce better speech quality (Worthington et al, 1987, Zarb & Schmitt, 1990; Jemt, 1994).

5.1.7 SUMMARY OF LITERATURE

Research and clinical experience have confirmed that tooth loss and replacement with dental prostheses may cause deterioration in some aspects of speech performance, particularly in the early stages following denture insertion. The response to changes in oral morphology due to denture wearing will vary according to the subject's adaptation capacity, and the adaptation process is more rapid in young subjects than in the elderly (Silverman, 1978; Hamlet and Stone, 1982).

Many factors in the area of complete and partial denture design have been found to have an effect on speech production. The design of the palatal connector of the maxillary prosthesis and the position of the maxillary incisor teeth are important factors, especially for articulation of the /S/ sound. In addition, the tongue space, occlusal vertical dimension, occlusal plane and the width of the alveolar ridges are of importance with respect to speech articulation.

It has been reported in studies of complete denture patients that the form of the anterior region of the denture base, from canine to canine, is most crucial with respect to speech deterioration and any increase in palatal thickness in this area of more than 1.5 mm may make speech difficult (Allen, 1958; Petrovic, 1974; Ritchie & Ariffin, 1982). It has been suggested that the palatal denture surface, where the tongue makes contact, should be kept as thin as possible to avoid any interference with speech production, particularly important for the articulation of the /S/ and /Z/ sounds (Silverman, 1967; Tanaka, 1973; Goyal & Greenstein, 1982; Ichikawa et al, 1995).

It is evident from studies in phonetics that the correlation between the quality of speech and denture morphology is marked and that replacement of the missing teeth and their supporting structures by an artificial substitute may alter the articulatory mechanism (Kaires, 1957; Tallgren, 1967; Silverman, 1967; Pounds, 1970; Sherman, 1970; Tanaka, 1973; Ritchie & Ariffin, 1982; Petrovic, 1985;

MacGregor, 1989; Jemt, 1991; Lundqvist et al, 1992; Lundqvist, 1993; Gross & Ormianer, 1994).

The fricative consonant sounds /S/, /Z/, /F/, /V/, /SH/, /ZH/, /TH/, /DH/ are most likely be affected in case of malocclusion and in patients wearing orthodontic or prosthodontic appliances (Ylppo, 1955; Lawson & Bond, 1969). Normally the /S/ sound is produced by friction of the air stream as it passes through a thin slit-like channel between the anterior part of the tongue and the palatal mucosa immediately posterior to the maxillary central incisors. Therefore, care must be taken while setting these teeth during complete denture construction. If the upper central incisors have been placed palatally and the lower central incisors lingually, alteration in speech may result due to a change in the relationship of tongue and these teeth. The /S/ channel will become thin and the /S/ sound will be pronounced /TH/. If the upper central incisors are kept too far labially, the slit-like channel will become thicker resulting in a change of the /S/ sound to /SH/. Similar speech distortion, particularly with /S/ sound, could be expected if the palatal aspect of the maxillary denture is too thick, specifically over the anterior part of the hard palate (Allen, 1958; Petrovic, 1974,1985; Hamlet and Stone, 1978; Ritchie & Ariffin, 1982; Komoda et al, 1991).

Several studies have reported varying periods of adaptation immediately after denture insertion. In some studies patients have returned to intelligible speech after one to three weeks (Allen, 1985, Boucher, 1970; Tanaka, 1973; Petrovic, 1985), while other patients experience difficulty for one month or more (Troffer & Beder, 1961; Bergman & Carlsson, 1972; Matsuki, 1972; Hamlet and Stone, 1978). Petrovic (1985) stated that in terms of speech, total adaptation to a new complete denture might take eight months and that the time involved is strongly dependant on the patients' hearing perception capability. Silverman (1978) and Hamlet and Stone (1982) reported that elderly people with new complete dentures experience greatest difficulty in adapting their speech to new prostheses.

Despite the substantial improvement in oral function found with the use of osseointegrated dental implants, there have been a number of reports which have highlighted patient concerns with speech and aesthetic aspects of treatment (Haraldson & Carlsson, 1977; Lindquist, 1987; Haraldson & Zarb, 1988; Lundqvist et al, 1992; Lundqvist, 1993). Jemt (1991) reported that 53% of patients treated with implant-supported fixed prostheses experienced difficulties with speech, particularly during the first weeks or months after restoration, when evaluated by means of questionnaires.

Lundqvist et al (1992 a & b) and Lundqvist (1993) studied the effect of implant-supported prostheses on patients' speech, with the use of subjective self-assessment questionnaires and the use of objective measures, by mean of perceptual and acoustic analysis. It was reported that 60% of the patients had speech problems, mainly associated with the pronunciation of the /S/ and /T/ sounds. Three years later, 31% of patients in this group still had a deteriorated speech. Hearing impairments or defects significantly contributed to the speech difficulties, particularly in the /S/ sound and it is shown in audiological examination that 67% of patients in the same study had hearing problems.

5.2 SPEECH IN PATIENTS WITH MODIFIED IMPLANT-RETAINED OVERDENTURES IN THE MAXILLARY ARCH

5.2.1 Aims of the present study

The aim of this study was to examine if objective speech analysis could provide significant quantitative information about the quality of speech in implant patients, and to examine the use of speech analysis methods such as perceptual and audiological analysis. In this context, it was a primary objective to investigate if there was contrast between full palatal coverage or partial coverage in the edentulous maxillary arch.

5.2.2 Patient selection

Four female patients, age between 39 to 70 years (mean 53 years) were included in this study. All had been edentulous for at least five years and all had been unable to tolerate conventional complete dentures. All patients had been provided with maxillary implant retained overdentures retained by at least two implant fixtures, which had been functioning for a period of at least 4 years. Each patients' age and the dental situation in the opposing arch are shown in **Table 5.1**.

Patient No.	Age	Opposing arch prosthesis
1	39	implant-overdenture
2	42	implant-overdenture
3	61	anterior natural teeth posterior fixed bridges
4	70	anterior natural teeth, free-end saddle partial denture

Table 5.1: Patient's age and type of opposing arch prosthesis

5.2.3 Clinical procedures

The aim of the study was explained to the patients and in each case an appointment schedule was set-up. Impressions were taken and the full coverage maxillary denture was duplicated using self-cure acrylic resin in order to copy the exact features of the existing denture, including the tooth position. Master impressions were taken using the replica dentures as individual trays, and the teeth were set-up according to the existing jaw registration and without changes to the tooth position **(Fig 5.1)**. After the trial stage the gold matrices were located **(Fig 5.2)** and the outline of maxillary denture base was marked on the master cast, 2mm posterior to the incisive papilla and running 3 mm palatal to the implant abutments **(Fig.5.3)**. Thereafter, the dentures were processed **(Fig.5.4)**.

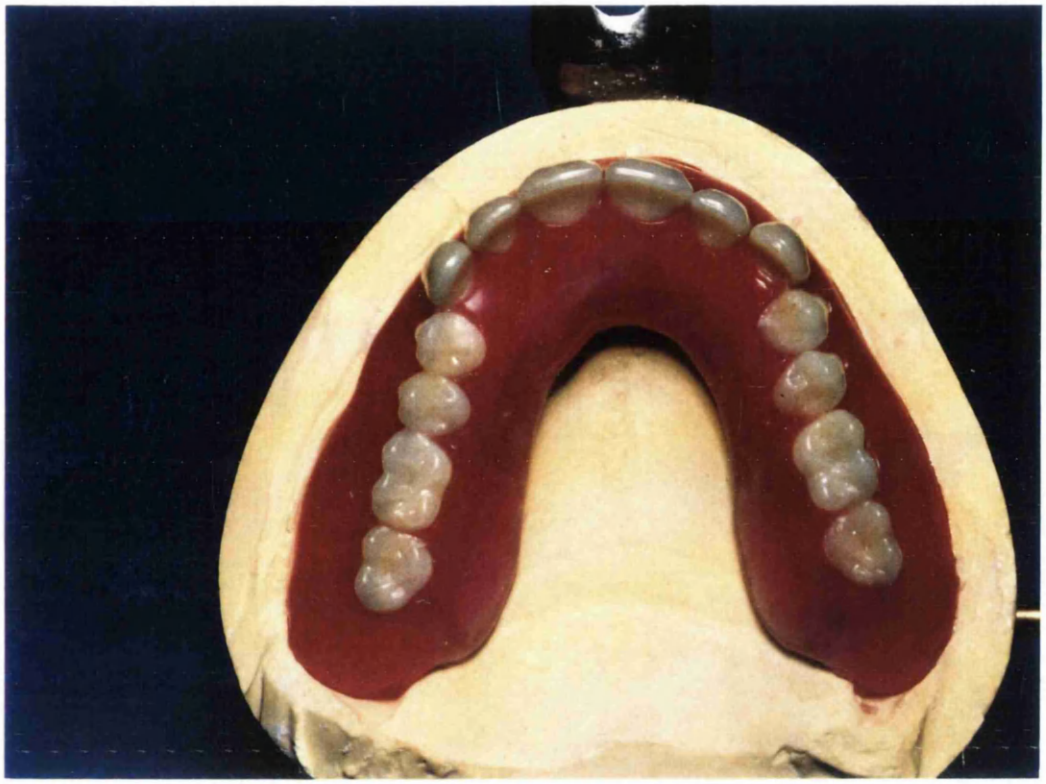

Fig.5.1 Wax denture with the tooth position copied.

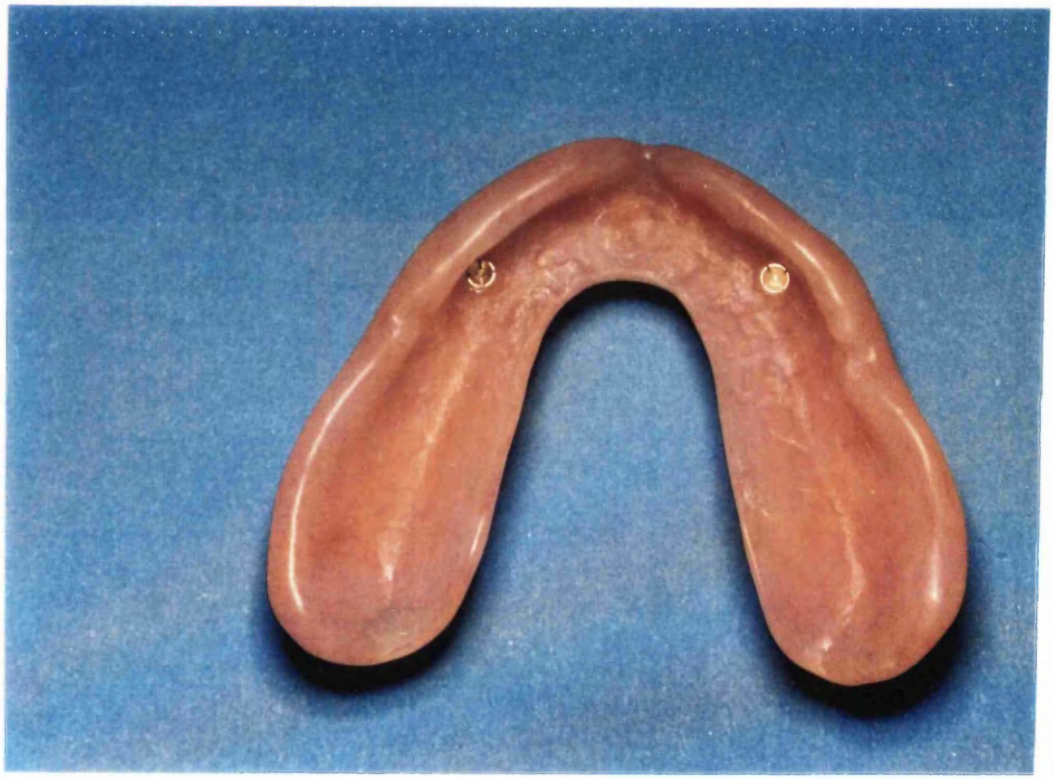

Fig.5.2 Locating the sites of ball attachment

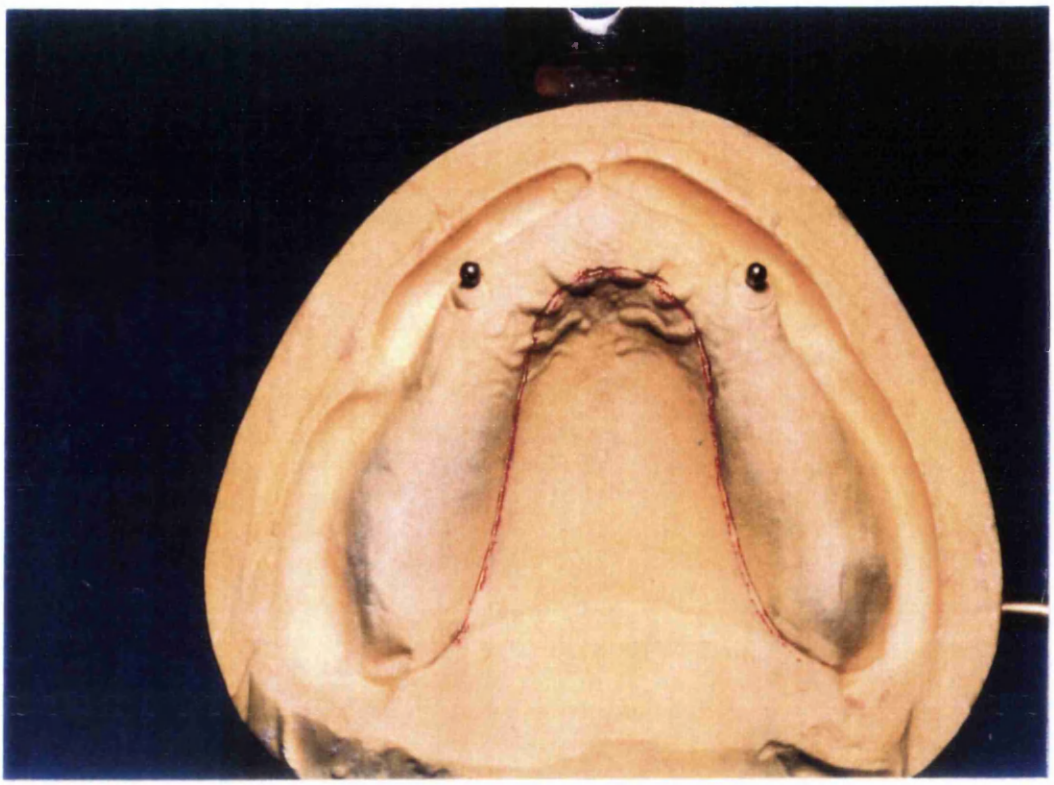

Fig.5.3 Mater cast with denture base outline.

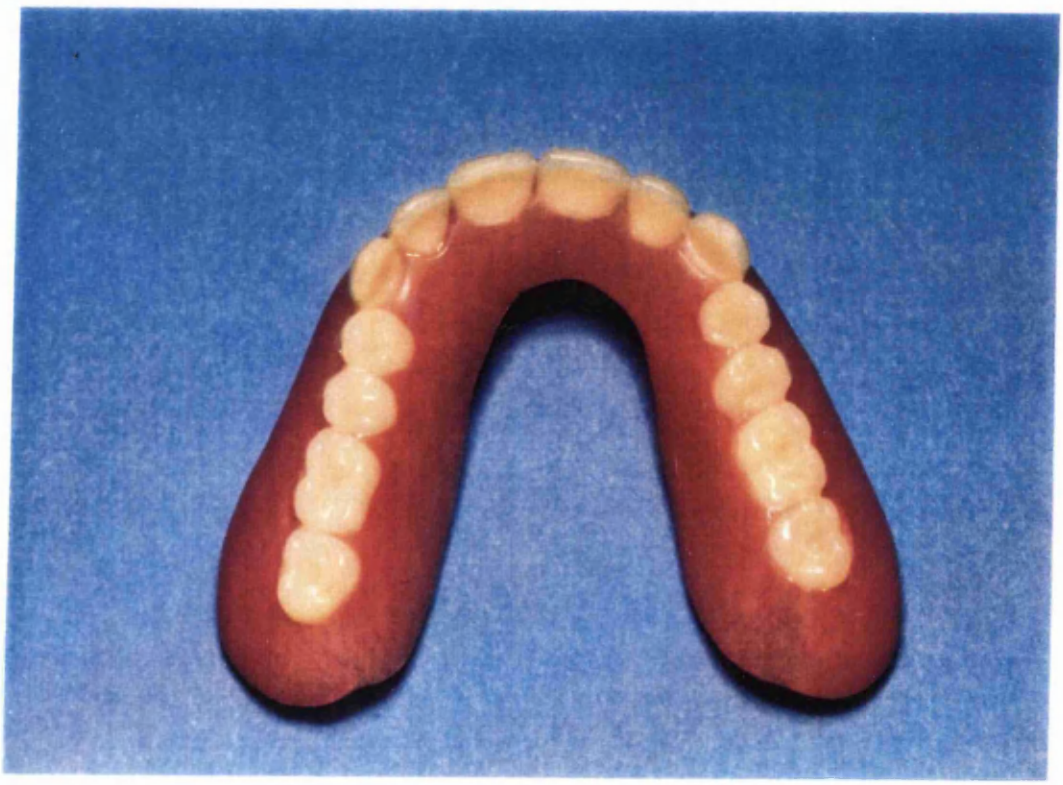

Fig.5.4 Finished denture

5.2.4 Speech recording sessions

Speech was recorded, started and analysed using a software programme (Dr Alan Wrench, Queen Margaret College, Edinburgh). This software was designed particularly to test speech quality in patients with congenital and acquired oral defects, before and after surgery. The first speech recording was carried out with the patients wearing their original implant-retained maxillary overdentures, which had been constructed with full palatal coverage. The speech recordings were made using a microphone linked directly to a personal computer (Elonex-425). Patients were seated in a quiet room in an upright position in front of the computer, and were able to read the words from a word list on the monitor screen **(Fig.5.5)**. The head-worn microphone (Shure SM10A, Dynamic-Mexico) was secured on the patient's head, with the microphone mouth-piece half an inch from corner of the mouth, according to the manufacture's instructions. The recording procedure was explained and a short rehearsal was carried out for each patient to enable the patients to become accustomed to the apparatus. There was enough time between each test word to enable the patients to understand and pronounce the word normally. The 70 selected words were from the Kent word-list, Kent et al (1989) **(Appendix 5.1)**. Each recording session lasted 10-15 minutes.

A second recording session was carried out two weeks after the delivery of the new dentures, which had been constructed to give reduced palatal coverage **(Fig.5.6)**, as described above **(5.2.3)** The recording procedures were replicated for both sessions.

Fig.5.5 Speech recording procedure

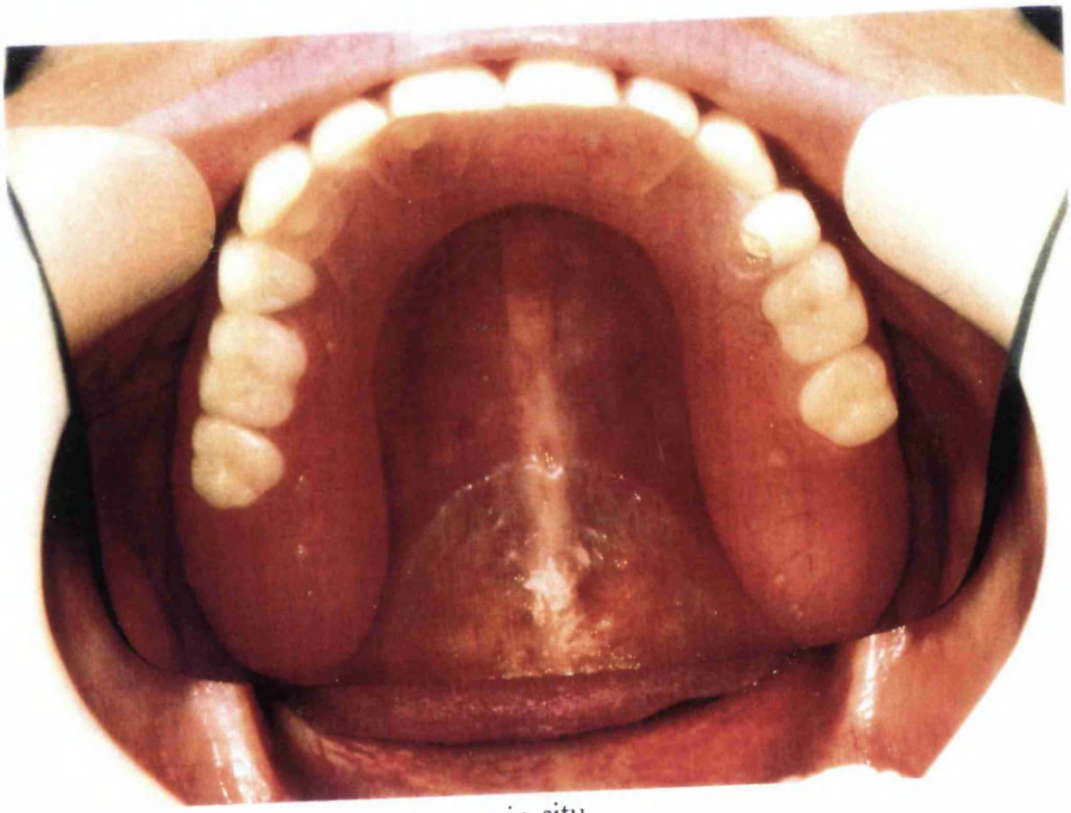

Fig.5.6 The modified upper denture in-situ

5.2.5 Audiological analysis

As it has been reported that there is a close link between hearing and speech adaptation (Perkins & Kent, 1986; Lundqvist et al, 1992 a,b), audiological investigations were carried out using Rinne's test and Weber's test in the assessment of hearing for each subject.

Rinne's test compares the relative efficiencies of sound transmission through the middle ear by air conduction and by bone conduction. In order to carry out the test each patient was seated in an upright position on the dental chair and tuning fork of 512 Hz struck and held close to the patient's ears. The vibrating fork was then placed firmly on the mastoid process and each patient asked to indicate whether hearing was better with the fork on the mastoid process (bone conduction) **(Fig.5.7)** or with the fork in front of the ear (air conduction) **(Fig.5.8)**. If sound transmission from the tuning fork is heard more clearly by air conduction (AC) than by bone conduction (BC) this indicates that the middle and outer ears are functioning normally (Rinne positive). If bone conduction is more effective than air conduction, it indicates that there is defective function of the outer or the middle ear (Rinne negative).

Weber's test is useful in determining the type of deafness a patient may have and in deciding which ear has the better functioning cochlea. The test is carried out by placing the base of the vibrating tuning fork firmly on the vertex of the head and asking the patient to identify whether the sound is heard centrally or is referred to one or other ear **(Fig.5.9)**. In conductive deafness the sound is heard in the deafer ear, while in sensorineural deafness the sound is heard in the better hearing ear.

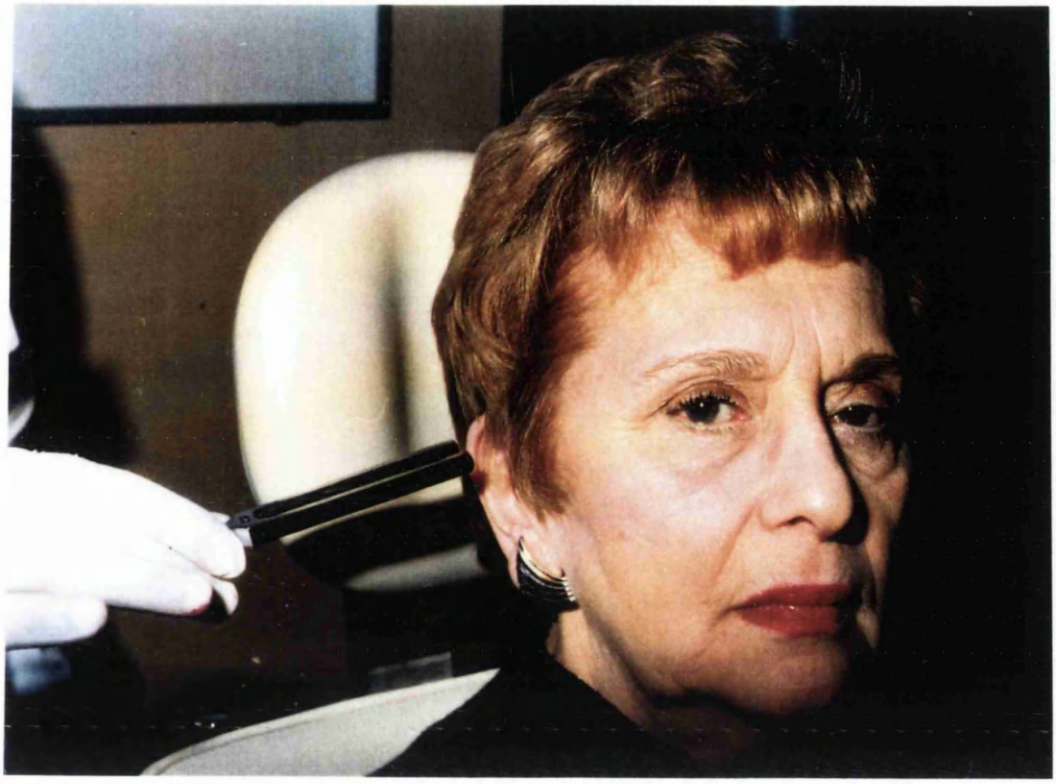

Fig.5.7 Testing air conduction

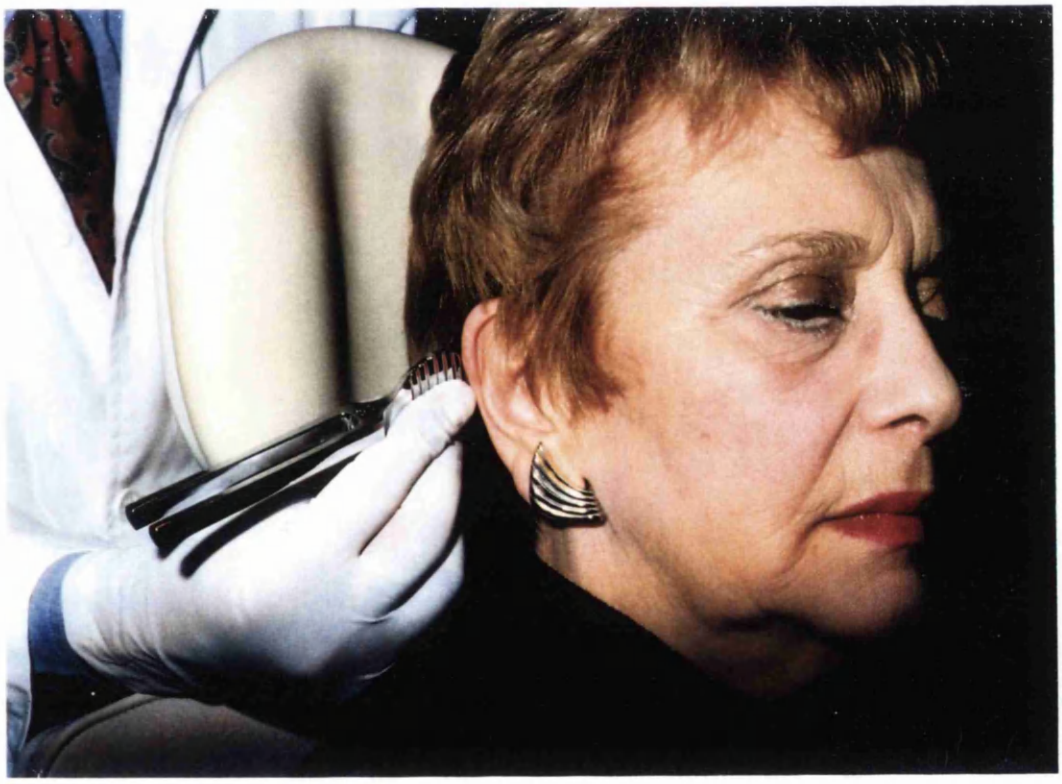

Fig.5.8 Testing bone conduction

Fig.5.9 Weber's test

5.2.6 Objective assessment of speech by listening panel

The speech sounds were judged by two panels of listeners: the first group were individuals involved in the field of speech pathology (expert panel), while the second group were neither speech pathologist nor dentists (non-expert panel). All were native speaker without any hearing problems.

5.2.6.1 Intelligibility test

The non-expert group listened to the recordings of the two sessions for each of the four experimental subjects with full palatal coverage and after denture modification. For assessment by the non-expert panel, the words were transferred to audio-tape using a tape recorder (SONY, Cassette-Corder, Japan). On an individual basis the members of the panel were seated in a quiet room and given detailed instructions on procedure. The task for the panelists was to listen to each recorded word from each

session and to match it with one of the four words, indicated on a form provided. For example, when the word *bad* was the target recorded word the panel had the option of selecting from the words *bat, bad, bed* and *pad* which closely correspond to the target word (**Appendix 5.2**). A similar procedure was followed for the other words on the word list with three alternatives in addition to each spoken word.

Initial analysis was carried out to check for the clarity before and after denture modification based on non-expert judgement. None of the three non-expert listeners detected any difference between the recorded words in the sessions recorded before and after denture modification. For this reason, it was not considered meaningful to have this form of assessment repeated by the expert panel.

5.2.6.2 Word-paired comparison test

This test was devised after failure of the intelligibility test to detect a difference between the pre- and post-denture modification recorded sessions. The recordings for full palatal coverage and restricted palatal coverage for each word on the Kent word list were arranged in pairs consecutively in a database programme which was designed for the purpose of this study.

The expert and the non-expert groups were asked to judge the speech on a five point scale where 1=preference for first token (word), 2=slight preference for first token, 3=no preference, 4=slight preference for second token, 5=preference for second token. Each listener was asked to identify which recording was the clearer, or to indicate if there was no difference in sound quality between the two word recordings. The listeners were unaware which of the word sample was recorded before denture modification and which was recorded after denture modification.

5.2.6.3 Speech Database Software

The software for this study was written to provide automated processing for all data used, by simplifying the following tasks:

- Sorting of speech data into word pairs.
- Playing of speech pairs to several independent listeners.
- Storage of the results.

Due to the large number of sample pairs, the study would have been time consuming and error prone without this automated data handling. The software was developed using Borland C++ v4.0 and designed to run under Microsoft Windows 3.1/95. A simple user interface was created, using a dialog box model with text input, static text and button controls. To simplify the user interface, it was decided to split the program into three separate parts; word pair sorting, pilot study scoring and main study scoring. A word pair sorting tool was designed to check that all the word pairs were matched before the panels started their task. When the software was initially started, it would ask the listener to identify him or herself from the list of six names. A continuous record was kept of each person's progress so they could switch off the computer and continue at a later time.

Each listener was presented with each word pair in turn. This pairing could be replayed as often as required. Five buttons were used to allow the listeners to score word-each pair according to the scoring system. The software randomly reversed the order of each sample pair (50% probability) when it was reached. When this occurred, the score given by each of the five buttons was also revered by the computer, i.e. a score of "1" *always* denoted a "strong preference for the 1st sample". The final scoring data for each listener was saved to disk as a plain ASCII comma separated values file. Such a format can easily be imported into most statistics, spreadsheet and database applications for the PC. Finally, all files used were stored on a Novell file server with password protection and daily backups to minimise the risk of data tampering or loss.

5.2.7 RESULTS

5.2.7.1 Audiological analysis

Audiological investigations were carried out for all four patients using a tuning fork with the use of both Rinnes' and Webers' tests. It was reported that only one patient had normal hearing, two patients had mild hearing loss with defective function of the outer or middle ear, and one patient had sensorineural hearing loss in the right ear.

5.2.7.2 Intelligibility test

The speech sounds were judged only by the members of the non-expert panel who listened to the recordings of two sessions, one with full palatal coverage and the other after denture modification.

After denture modification, because of difficulties in data transfer only 61 of the total of 70 single words an the Kent word list were available for use in assessing the intelligibility of speech for *patient 1.* Prior to denture modification, with full coverage, there was agreement for 54 out of the 61 words between all three members of the non-expert panel. After denture modification all three panel members were in agreement for 57 of the 61 words.

All seventy of the words from the Kent word-list were available for assessment of speech intelligibility for *patient 2.* Prior to denture modification there was agreement between all three members of the non-expert panel for 69 out of the 70 words. After denture modification all three panel members were in agreement for 67 out of the 70 words.

Again because of difficulties in data transfer, only 69 out of 70 single words were assessed for *patient 3.* Before denture modification there was agreement between all three members of the non-expert panel for all of the recorded 69 words. After denture modification all three panel members were in agreement for all of the 69 words.

All seventy of the words from the Kent word-list were available for assessment of speech intelligibility for *patient 4*. Prior to denture modification there was agreement between all three members of the non-expert panel for 66 out of the 70 words. After denture modification all three panel members were in agreement for 66 out of the 70 words.

In summary, the overall agreement between the three members of the non-expert panel before denture modification was 258 out of 270 words, and after denture modification the overall agreement was 259 out of 270 words.

As this method of assessment had not proved to be sufficiently discriminating in terms of identifying speech intelligibility before and after denture modification, it was discontinued and the use of a word-pair comparison test was introduced as an alternative method for speech assessment.

5.2.7.3 Word-paired comparison

2.5.7.3.1 Statistical analysis

In this study, with a restricted scale of measurement of five units and a non-normal distribution of data, a non-parametric test (distribution-free test) was considered the appropriate method for statistical analysis. Such tests apply to the distribution of values not to averages, and are based on ranking the data and using the median to test the significance level. The Wilcoxon Signed Ranks test is a non-parametric procedure for matched pair analysis and multi-comparisons. It was used in the present study to test for significance differences in speech clarity for the group of four patients, articulating each word in the Kent word list before and after upper denture modification.

Each subject read 70 words from the Kent Word List, before and after upper denture modification. Due to problems in data transfer, only 60 words were recorded for all patients before and after palatal modification, and this analysis is based on a restricted group of 60 words from the Kent-list which were available for analysis for all four patients both before and after denture modification. Speech quality with full palatal coverage and after palatal modification was analysed by three non-expert

listeners, who did not have any professional speech knowledge, and three expert listeners, involved in speech assessment on a professional basis. The word-pairs (before and after modification) were presented to the listeners in a random manner so that the listeners did not know which sample was recorded before modification and which was recorded after. The task of both the non-experts and experts was to identify which word in the pair seemed to have clearer articulation. A five point scale was used as follows:

1. Before palatal modification- speech clearly better.
2. Before palatal modification- speech slightly better.
3. No difference in speech quality before and after modification.
4. After palatal modification- speech slightly better.
5. After palatal modification- speech clearly better.

A total of 240 word-pairs were analysed by each listener (4 subjects - 60 word-pairs each). Thereafter the database programme corrected the selection of each word to the relevant scale.

To test the degree of agreement between the individual members of the panel on the effect of palatal modification on the quality of speech, comparison was carried out using the KAPPA values (Statistical Package of Social Science, SPSS). KAPPA values normally range from zero to one, with one indicating the highest possible level of agreement. A KAPPA value of zero means that the level of agreement is no better than chance. Negative KAPPA values indicate a correlation level less than that which would be expected by chance. The level of significance was tested at $p \leq 0.05$.

5.2.7.4 Agreement between Experts

From **Table 5.2** it obvious that that the three expert listeners used the 1 to 5 scale in totally different ways. **Expert 2** used the middle of the scale to a greater extent than the other two listeners **(Table 5.2)**. **Expert 1** found the incidence of change in the clarity of speech was relatively high 78.75% words were affected by the upper denture modification. **Expert 2** found that speech changes were evident in only 16.25% of the tested words after palatal modification and **Expert 3** found a

moderate proportion 58.75% of the tested samples were affected denture modification.

Expert No.1			Expert No.2			Expert No.3		
Scale	Count	Percent	Scale	Count	Percent	Scale	Count	Percent
1	90	37.50	1	7	2.92	1	55	22.92
2	9	3.75	2	16	6.67	2	12	5.00
3	51	21.25	3	201	83.75	3	99	41.25
4	13	5.42	4	8	3.33	4	12	5.00
5	77	32.08	5	8	3.33	5	62	25.83
N	**240**	100	**N**	**240**	100	**N**	**240**	100

Table 5.2: Expert listeners, summary statistics:

Agreement between Expert 1 and Expert 2 (Table 5.3)

There was agreement between these expert listeners in 49 of the 240 word-pairs (20.42%) that there was no appreciable change in speech quality after palatal modification. These expert listeners agreed that speech was clearly better before palatal modification for 5 word-pairs and in only 1 word-pair they agreed that speech was slightly better prior to denture modification. There was agreement in only 5 word-pairs that speech was clearly better after palatal modification. The overall level of agreement between the two listeners was 25%, the greater part of this being with respect to the perception of an absence of change in speech clarity after palatal modification. The KAPPA value was 0.058, indicating an extremely low level of agreement between these two expert listeners.

Scale	1	2	3	4	5	ALL
1	**5** **2.08%**	9 3.75	72 30.00	2 0.83	2 0.83	90 37.50
2	0 --	**1** **0.42%**	8 3.33	0 --	0 --	9 3.75
3	0 --	2 0.83	**49** **20.42%**	0 --	0 --	51 21.25
4	0 --	0 --	12 5.00	**0** --	1 0.42	13 5.42
5	2 0.83	4 1.67	60 25.00	6 2.50	**5** **2.08%**	77 32.08
ALL	7 2.92	16 6.67	201 83.75	8 3.33	8 3.33	**240** **100%**

Table 5.3: KAPPA assessment of **Experts 1** and **2** agreement in analysis of word pairs **Expert 1**-Columns. **Expert 2**-Rows.

Agreement between Expert 1 and Expert 3 (Table 5.4)

Expert 1 and **Expert 3** used the full range of the assessment scale to a greater degree than **Expert 2.** There was some agreement with respect to there being no appreciable change (27 word-pairs) after palatal modification, clearly better after modification (28 word-pairs). In 2 word-pairs they agreed that speech was slightly better after modification. However, in 25 word-pairs the two expert listeners agreed that speech was clearly better before palatal modification.. The overall agreement between the two expert listeners was 34.17% of the word-pairs **(Table 5.4)**. The KAPPA value was slightly higher than the value for expert 1 and 2 (0.109), but there was still a low level of agreement between these two expert listeners.

Scale	1	2	3	4	5	ALL
1	**25** **10.42%**	8 3.33	37 15.42	6 2.50	14 5.83	90 37.50
2	4 1.67	**0** --	3 1.25	0 --	2 0.83	9 3.75
3	8 3.33	1 0.42	**27** **11.25%**	1 0.42	14 5.83	51 21.25
4	2 0.83	0 --	5 2.08	**2** **0.83%**	4 1.67	13 5.42
5	16 6.67	3 1.25	27 11.25	3 1.25	**28** **11.67%**	77 32.08
ALL	55 22.92	12 5.00	99 41.25	12 5.00	62 25.83	**240** **100%**

Table 5.4: KAPPA assessment of **Experts 1** and **3** agreement in analysis of word pairs . **Expert 1**- Columns. **Expert 3** - Rows.

Agreement between Expert 2 and Expert 3 (Table 5.5)

Expert 2 concentrated in the middle scale of the scale to a greater extent than **Expert 3.** There was strong agreement between **Expert 2** and **Expert 3** with respect to there being no appreciable change in speech quality following denture modification (89 word-pairs, 37.08%). There was agreement that 6 word-pairs were clearly better before modification and 1 word-pair was slightly better before modification. In 3 word-pairs these expert listeners agreed that speech was clearly better after palatal modification. The overall agreement between the two listeners

was 41.25%, mainly because of the high level of agreement with respect to there being no appreciable change in speech quality **(Table 5.5)**. The KAPPA value was 0.074, indicating a very low level of agreement between these two expert listeners.

Scale	1	2	3	4	5	ALL
1	**6** **2.50%**	0 --	0 --	0 --	1 0.42	7 2.92
2	5 2.08	**1** **0.42%**	7 2.92	0 --	3 1.25	16 6.67
3	42 17.50	9 3.75	**89** **37.08%**	10 4.17	51 21.25	201 83.75
4	1 0.42	1 0.42	2 0.83	**0** --	4 1.56	8 3.33
5	1 0.42	1 0.42	1 0.42	2 0.83	**3** **1.25%**	8 3.33
ALL	55 22.92	12 5.00	99 41.25	12 5.00	62 25.83	**240** **100%**

Table 5.5: KAPPA assessment of **Experts 2** and **3** agreement in analysis of word pairs . **Expert 2**- Columns. **Expert 3**- Rows.

5.2.7.5 Rating of changes in speech quality for each patient by Experts Panel (Expert 1)

In order to assess if there were indications of any consistently identified changes in speech quality for any of the four patients in the experimental group after modification of the upper denture, examination of speech assessment values for each patient was carried out. The findings of **Expert 1** are presented in **Table 5.6**.

Patient 1	Count	Percent	Patient 2	Count	Percent
1	25	41.67	1	24	40.00
2	1	1.67	2	5	8.33
3	13	21.67	3	9	15.00
4	5	8.33	4	2	3.33
5	16	26.67	5	20	33.33
N	**60**	100	**N**	**60**	100
Patient 3	**Count**	**Percent**	**Patient 4**	**Count**	**Percent**
1	12	20.00	1	29	48.33
2	2	3.33	2	1	1.67
3	17	28.33	3	12	20.00
4	4	6.67	4	2	3.33
5	25	41.67	5	16	26.67
N	**60**	100	**N**	**60**	100

Table 5.6: Expert 1, ratings for each patient

The Wilcoxon signed rank test was used to test the hypothesis that there was no change in speech brought about by palatal modification. The null hypothesis that there was no change with palatal modification (if median value was 3) was rejected in favour of the hypothesis that the median was not 3 in those cases underlined in **Table 5.7** *(P≤0.05)*. This analysis indicated that one patient showed statistically significant changes in speech quality following upper denture modification as assessed by **Expert 1**. Patient No.3 showing a significant improvement in speech quality after palatal modification **(Table 5.7)**. There were no other significant changes after palatal modification.

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	449.5	0.228	3.000
2	598.0	0.545	3.000
3	639.0	**0.046**	**3.500**
4	420.0	0.086	3.000

Table 5.7: Patient 1-4, analysis of **Expert 1**.

Rating of changes in speech quality for each patient by Expert 2

The speech assessment values for each patient before and after palatal modification as evaluated by **Expert 2** are presented in **Table 5.8**.

Patient 1	Count	Percent	Patient 2	Count	Percent
1	3	5.00	1	4	6.67
2	6	10.00	2	2	3.33
3	45	75.00	3	53	88.33
4	2	3.33	4	0	0
5	4	6.67	5	1	1.67
N	**60**	100	**N**	**60**	100
Patient 3	**Count**	**Percent**	**Patient 4**	**Count**	**Percent**
1	0	0	1	0	0
2	4	6.67	2	4	6.67
3	47	78.33	3	56	93.33
4	6	10.00	4	0	0
5	3	5.00	5	0	0
N	**60**	100	**N**	**60**	100

Table 5.8: Expert 2, ratings for each patient.

Again the Wilcoxon signed rank test was used to test the hypothesis that there was no change in speech brought about by palatal modification, and there was no significant

change in speech quality in any of the four patients after palatal modification as assessed by **Expert 2 (Table 5.9)**

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	57.0	0.887	3.000
2	5.0	0.151	3.000
3	69.0	0.108	3.000
4	0.0	0.100	3.000

Table 5.9: Patient 1-4, analysis of **Expert 2.**

Rating of changes in speech quality for each patient by Expert 3

The speech assessment values for each patient before and after palatal modification as evaluated by **Expert 3** are presented in **Table 5.10**.

Patient 1	Count	Percent	Patient 2	Count	Percent
1	18	30.00	1	21	35.00
2	5	8.33	2	2	3.33
3	19	31.67	3	19	31.67
4	4	6.67	4	3	5.00
5	14	23.33	5	15	25.00
N	**60**	100	**N**	**60**	100
Patient 3	**Count**	**Percent**	**Patient 4**	**Count**	**Percent**
1	9	15.00	1	7	11.67
2	1	1.67	2	4	6.67
3	23	38.33	3	38	63.33
4	4	6.67	4	1	1.67
5	23	38.33	5	10	16.67
N	**60**	100	**N**	**60**	100

Table 5.10: Expert 3, ratings for each patient

The Wilcoxon test showed that only one patient exhibited statistically significant changes in speech quality after denture modification. Patient No.3 showed significant improvement in speech clarity after palatal modification. The remaining patients showed no significant changes after modification **(Table 5.11).**

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	377.0	0.492	3.000
2	361.5	0.375	3.000
3	506.5	**0.020**	**3.500**
4	143.0	0.603	3.000

Table 5.11: Patient 1-4, analysis of **Expert 3**.

In summary, the result of the overall assessment of the three expert listeners showed that one patient (No.3) was assessed as having improved speech after upper denture modification by the two of three listeners. The other three patients showed no significant change in speech clarity after palatal modification according to the assessment of the expert listeners.

5.2.7.6 Agreement between Non-Experts

From **Table 5.12** again it is clear that the three non-expert listeners also used the assessment scale in totally different ways from each other. **Non-Expert 1** found that speech quality in 90.83% word-pairs was affected by palatal modification, **Non-Expert 2** found a moderate proportion (57.92%) of the words tested were affected by denture modification as did **Non-Expert 3** (58.33%). It is clear from the summary data **(Table 5.12)** that **Non-Expert 2** and **Non-Expert 3** used the middle of the scale to a greater extent than did **Non-Expert 1**.

Non-Expert No.1			Non-Expert No.2			Non-Expert No.3		
Scale	**Count**	**Percent**	**Scale**	**Count**	**Percent**	**Scale**	**Count**	**Percent**
1	108	45.00	1	41	12.92	1	21	8.75
2	10	4.17	2	43	17.92	2	44	18.33
3	22	9.17	3	101	42.08	3	100	41.67
4	16	6.67	4	32	13.33	4	52	21.67
5	84	35.00	5	33	13.75	5	23	9.58
N	**240**	100	**N**	**240**	100	**N**	**240**	100

Table 5.12: Non-Experts, summary statistics

Agreement between Non-Expert 1 and Non-Expert 2 (Table 5.13)

There was agreement between **Non-Expert 1** and **Non-Expert 2** with respect to there being greater speech clarity before modification of the upper denture in 14 (5.83%) word-pairs. There was agreement that speech quality was slightly better prior to palatal modification for 4 word-pairs and in 9 word-pairs there was agreement that speech was not affected by denture modification. Only in 1 word-pair there was agreement that speech quality was slightly better after palatal modification and in 11 word-pairs these listeners agreed that speech was clearly better after modification. The overall agreement between the two listeners was 16.25%, the greater part of this being with respect to there being greater speech clarity before palatal modification. The KAPPA value based on 60-word pairs for four subjects was 0.002, indicating very low level of agreement between the two listeners.

Scale	1	2	3	4	5	ALL
1	**14** **5.83%**	20 8.33	48 20.00	9 3.75	17 7.08	108 45.00
2	1 0.42	**4** **1.67%**	4 1.67	1 0.42	0 --	10 4.17
3	0 --	6 2.50	**9** **3.75%**	5 2.08	2 0.83	22 9.17
4	2 0.83	2 0.83	8 3.33	**1** **0.42%**	3 1.25	16 6.67
5	14 5.83	11 4.58	32 13.33	16 6.67	**11** **4.58%**	84 35.00
ALL	31 12.92	43 17.92	101 42.08	32 13.33	33 13.75	**240** **100%**

Table 5.13: KAPPA assessment of **Non-Experts 1 & 2** agreement in analysis of word pairs **Non-Expert 1**-Columns. **Non-Expert 2**-Rows.

Agreement between Non-Expert 1 and Non-Expert 3 (Table 5.14)

Non-Expert 1 used the assessment scale in both extremes more than **Non-Expert 3** who used mostly the middle of the scale. There was agreement with respect there being greater speech clarity before palatal modification in 13 (5.42%) word-pairs. There was agreement that speech was slightly clearer before denture modification in 2 word-pairs, and there was agreement in 10 word-pairs that speech was unaffected by palatal modification. In 4 word-pairs these listeners agreed that speech was slightly better after palatal modification and in 8 word-pairs there was agreement that speech was clearly better after modification. The overall agreement between the two non-expert listeners was 15.42% of the word-pairs. The KAPPA value was 0.024 indicating very poor agreement between the two listeners.

Scale	1	2	3	4	5	ALL
1	**13** **5.42%**	20 8.33	47 19.58	17 7.08	11 4.58	108 45.00
2	2 0.83	**2** **0.83%**	4 1.67	1 0.42	1 0.42	10 4.17
3	1 0.42	5 2.08	**10** **4.17%**	5 2.08	1 0.42	22 9.17
4	1 0.42	3 1.25	6 2.50	**4** **1.67%**	2 0.83	16 6.67
5	4 1.67	14 5.83	33 13.75	25 10.42	**8** **3.33%**	84 35.00
ALL	21 8.75	44 18.33	100 41.67	52 21.67	23 9.58	**240** **100%**

Table 5.14: KAPPA assessment of **Non-Expert 1 & 3** agreement in analysis of word pairs **Non-Expert 1**-Columns. **Non-Expert 3**-Rows.

Agreement between Non-expert 2 and Non-Expert 3 (Table 5.15)

Both **Non-Expert 2** and **Non-Expert 3** used the assessment scale with more concentration in the middle of the scale. There was agreement with respect to there being no appreciable change in speech quality in 58 word-pairs (24.17%) after palatal modification. There was agreement that speech quality was clearly better in 6 word-pairs before modification and slightly better in 12 word-pairs before modification. These listeners agreed that speech was slightly better in 12 word-pairs following palatal modification and they agreed that speech clarity was much better in 9 word-pairs after modification. The overall agreement between the two listeners was 40.42%. The KAPPA value (0.193) for these two non-experts was slightly higher than the KAPPA values of the other comparisons, but there was still very poor agreement.

Scale	1	2	3	4	5	ALL
1	**6** **2.50%**	9 3.75	12 5.00	4 1.67	0 --	31 12.92
2	7 2.92	**12** **5.00%**	13 5.42	7 2.92	4 1.67	43 17.92
3	3 1.25	16 6.67	**58** **24.17%**	18 7.50	6 2.50	101 42.08
4	3 1.25	6 2.50	7 2.92	**12** **5.00%**	4 1.67	32 13.33
5	2 0.83	1 0.42	10 4.17	11 4.58	**9** **3.75%**	33 13.75
ALL	21 8.75	44 18.33	100 41.67	52 21.67	23 9.58	**240** **100%**

Table 5.15: KAPPA assessment of **Non-Expert 2** & **3** agreement in analysis of word pairs. **Non-Expert 2**-Columns. **Non-Expert 3**-Rows.

The highest level of overall agreement (40.42%) was found between **Non-Expert 2** and **Non-Expert 3** and this occurred because both listeners indicated in a large proportion of instances there was no appreciable change in the clarity of speech associated with upper denture modification.

5.2.7.7 Rating of changes in speech quality for each patient by Non-Experts Panel (Non-Expert 1)

In order to assess whether there were consistently identified changes in speech clarity after palatal modification for any of the patients in the experimental group, examination of speech assessment values for each patient was carried out. The findings of **Non-Expert 1** are presented in **Table 5.16**.

Patient 1	Count	Percent	Patient 2	Count	Percent
1	41	68.33	1	17	28.33
2	2	3.33	2	1	1.67
3	4	6.67	3	5	8.33
4	1	1.67	4	3	5.00
5	12	20.00	5	34	56.67
N	**60**	100	**N**	**60**	100
Patient 3	**Count**	**Percent**	**Patient 4**	**Count**	**Percent**
1	21	35.00	1	29	68.33
2	2	3.33	2	5	3.33
3	9	15.00	3	4	6.67
4	6	10.00	4	6	10.00
5	22	36.67	5	16	20.00
N	**60**	100	**N**	**60**	100

Table 5.16 : Non-Expert 1, ratings for each patient.

The Wilcoxon signed rank test was used to test the hypothesis that there was no change in speech brought about by implant treatment. The null hypothesis that there was no change with implant treatment (if median value was 3) was rejected in favour of the hypothesis that the median was not 3 in those cases underlined in **Table 5.17** *($P \leq 0.05$)*. The analysis showed that two patients showed statistically significant changes in speech quality after palatal modification as assessed by **Non-Expert 1**. Patient No.1 showed significantly poorer speech after denture modification, while patient No.2 showed a significant improvement in speech clarity after palatal modification. The other two patients showed no significant change after modification of the upper denture.

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	362.0	**0.000**	**1.500**
2	1027.5	**0.031**	**3.500**
3	687.0	0.826	3.000
4	580.0	0.076	3.000

Table 5.17: Patient 1-4, analysis of **Non-Expert 1.**

Rating of changes in speech quality for each patient by Non-Expert 2

Speech assessment values for each patient on an individual basis, before and after modification as estimated by **Non-Expert 2** are presented in **Table 5.18**.

Patient 1	Count	Percent	Patient 2	Count	Percent
1	8	13.33	1	19	31.67
2	12	20.00	2	14	23.33
3	19	31.67	3	15	25.00
4	7	11.67	4	6	10.00
5	14	23.33	5	6	10.00
N	**60**	100	**N**	**60**	100
Patient 3	**Count**	**Percent**	**Patient 4**	**Count**	**Percent**
1	3	5.00	1	1	1.67
2	10	16.67	2	7	11.67
3	21	35.00	3	46	76.67
4	13	21.67	4	6	10.00
5	13	21.67	5	0	0
N	**60**	100	**N**	**60**	100

Table 5.18: Non-Expert 2, ratings for each patient

There were significant changes in speech quality following palatal modification evident in patients No.2 and No.3 **(Table 5.19)**. Patient No.2 showed significantly poorer speech after palatal modification, while patient No.3 showed a significant improvement in speech clarity after modification. The other two patients showed no significant changes in speech quality after modification, according to the assessment of **Non-Expert 2**.

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	497.0	0.392	3.000
2	261.0	**0.004**	**2.500**
3	565.5	**0.015**	**3.500**
4	42.0	0.530	3.000

Table 5.19: Patient 1-4, analysis of **Non-Expert 2.**

Rating of changes in speech quality for each patient by Non-Expert 3

Speech assessment values for each patient before and after treatment for **Non-Expert 3** are presented in **Table 5.20**.

Patient 1	Count	Percent	Patient 2	Count	Percent
1	10	16.67	1	5	8.33
2	12	20.00	2	11	18.33
3	21	35.00	3	29	48.33
4	13	21.67	4	12	20.00
5	4	6.67	5	63	5.00
N	**60**	100	**N**	**60**	100
Patient 3	**Count**	**Percent**	**Patient 4**	**Count**	**Percent**
1	2	3.33	1	4	6.67
2	6	10.00	2	15	25.00
3	22	36.67	3	28	46.67
4	16	26.67	4	11	18.33
5	14	23.33	5	2	3.33
N	**60**	100	**N**	**60**	100

Table 5.20: Non-Expert 3, ratings for each patient

The Wilcoxon test showed that only one patient (No.3) exhibited significant improvement in speech clarity after palatal modification. No other patient showed significant changes in speech quality after modification **(Table 1.21)**.

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	299.0	0.207	3.000
2	226.5	0.681	3.000
3	611.0	**0.001**	**3.500**
4	207.5	0.295	3.000

Table 5.21: Patient 1-4, analysis of **Non-expert 3**.

In summary, the result of the overall estimation of the three non-expert listeners showed that two patients (No.1 & 2) were assessed showing poorer speech quality palatal modification by Non-Expert 1 and 2. Two of the three Non-Experts agreed that patient No.3 showed significant improvement in speech clarity after upper denture modification. Patient No.4 showed no change in speech quality in the assessment of all three Non-Expert listeners.

The level of agreement between Experts and Non-Experts (inter-judgement reliability) was obtained. In addition the measurement of the intra-judgement reliability between the Non-Experts and the Experts group was based on all 60 word-pairs for the four subjects. The findings of KAPPA analysis indicated very low agreement levels between the members of the listening panels **(Table 5.22)**. The highest KAPPA value between **Non-Expert 2** and **Non-Expert 3**, was 0.193, still indicating very low agreement. The Kappa values (as a measure of agreement levels) for agreement between the Expert listeners were slightly higher (0.058, 0.109 and 0.074) than for the Non-Expert listeners (0.002, 0.024 and 0.193).

	Non-Exp.1	**Non-Exp.2**	**Non-Exp.3**	**Expert 1**	**Expert 2**	**Expert 3**
Non-Exp.1	--	--	--	--	--	--
Non-Exp.2	0.002	--	--	--	--	--
Non-Exp.3	0.024	**0.193**	--	--	--	--
Expert 1	0.010	0.129	0.065	--	--	--
Expert 2	0.016	0.090	0.115	0.058	--	--
Expert 3	0.039	0.179	0.170	0.109	0.074	--

Table 5.22: Kappa values based on 60 word-pairs for all four both non-experts and experts listeners.

5.2.8 DISCUSSION

It is evident from studies in phonetics that there is a reported correlation between the quality of speech and denture morphology and that replacement of missing teeth and their supporting structures by an artificial substitute may alter the articulatory mechanism. In this study, four female patients, already wearing an upper implant-retained overdenture were evaluated using a speech software programme to investigate whether there was a difference in speech quality between full palatal coverage and partial palatal coverage. Speech quality before and after modification was assessed by expert and non-expert listeners in two tests; the word intelligibility test and the word-pair comparison test.

A simple method used to assess the hearing mechanism identified that three patients had hearing defects in the outer or the middle ear, without specifying the actual cause or whether this was pathological or mechanical. One patient had normal hearing.

A total of 270 words were analysed using the intelligibility test, and overall accuracy in word identification with the non-expert listeners was 254 words (94.6%) before palatal modification and 259 words (96.3%) after upper denture modification. Thus, there was a very high level of speech intelligibility both before and after palatal modification, based on the assessment of the three non-expert listeners. It is possible that, despite the fact that the patients had been denture wearers for long time, they may have required some additional time to adjust to the major change in palatal contour of the upper denture and the two weeks given to them was not enough to detect an improvement in speech after modification. Troffer and Beder (1961), Bergman and Carlsson (1972), Matsuki (1972) and Hamlet et al (1978) have reported that some subjects required months to adapt to a new prostheses, Nevertheless, after palatal modification all four patients reported that speech clarity was much better than with full coverage. No patient indicated a wish to return to wearing a full palatal coverage maxillary denture.

Because of the failure of the intelligibility test to detect differences between the words from the Kent list before and after palatal modification, an alternative

approach to speech assessment was decided upon and a word paired comparison test was used. A total of 240 word-pairs were analysed by each expert and non-expert listener. A common finding in this study was that both expert and non-expert panels used the five-point scale in totally different ways.

The KAPPA values test showed that experts 1 and 2 agreed that in 49 word-pairs there was no change in speech quality after palatal modification, that there was speech improvement in 5 word-pairs after patients being provided by the modified upper denture and that there was better speech with full palatal coverage in 6 word-pairs. Experts 1 and 3 agreed that in 27 word-pairs there was no change in speech clarity following palatal modification. There was agreement in 25 word-pairs that showed better speech clarity with the full palatal coverage and 30 word-pairs showed improvement after upper denture modification. In 89 word-pairs experts 2 and 3 agreed that there was no effect induced by palatal modification. All three of the expert listeners agreed in the majority of the recorded words there was no appreciable change in speech clarity associated with the modification of the upper denture, and the highest level of overall agreement was found between experts 2 and 3.

One patient (No.3) was assessed as having improved speech after palatal modification by two of the three expert listeners. Two factors may have contributed to speech improvement in this particular patient; this patient had both upper and lower implant-retained overdentures and she was the youngest of the four subjects. Silverman (1978) and Hamlet & Stone (1982), have reported that the adaptation process is more rapid in young subjects than in the elderly. Hearing impairment may have been an important factor, particularly in the three patients who did not show any change in speech quality (Perkins and Kent, 1986; Lundqvist et al, 1992 a,b).

The KAPPA analysis showed agreement between non-experts 1 and 2 that in 18 word-pairs there was better speech before palatal modification and there was speech improvement in 12 word-pairs after patients had been provided with the modified upper denture. Non-experts 1 and 3 agreed in 15 word-pairs that there was better speech clarity with full palatal coverage, and that 12 word-pairs showed a

significant improvement in speech clarity after modification of the upper denture. In the majority of the recorded words (58 word-pairs) non-experts 2 and 3 agreed that there was no effect induced by palatal modification, in 18 word-pairs there was better speech with the full coverage denture and in 21 word-pairs these listeners agreed that there was significant improvement in speech clarity after palatal modification. However, this finding indicated that all three non-expert listeners agreed in the majority of the recorded words there was no appreciable change in speech clarity associated with the modified upper denture and the highest level of overall agreement was found between non-experts 2 and 3.

It was reported that two patients were assessed as having poorer speech after palatal modification, and this could have been due to hearing impairments in these patients. Two of the non-experts agreed that patient (No.3) had showed significant improvement in speech clarity after palatal modification. It may have been significant that patient No.3 had both upper and lower implant-retained overdentures, she was the only patient with normal hearing and she was the youngest of the four patients tested.

A factors which may have been of importance in determining the outcome of this study was the fact that the tested words, selected from Kent word list, were recorded as single word samples, where the patient was given the time to read each individual word on the computer screen. This might have been a factor limiting the discrepancies in speech before and after palatal modification, as the patients were given enough time to read each single word sample comfortably with full concentration. On the other hand, all of the patients complained of at least some speech difficulty before denture modification, and they all reported an improvement in conversational speech after denture modification. In some other studies patients have been asked to read sentences which emphasised the /S/ sound, such as in the study by Ghi & McGivney (1979) where the test piece, "I crossed the Mississippi river in 1776" was used. Chierici et al (1978) and Goyal & Greenstein (1982) have also used sentences which simulate the public dialogue to test speech clarity.

5.3 SPEECH IN PATIENTS WITH MANDIBULAR IMPLANT-RETAINED OVERDENTURES

5.3.1 Aims of this present study

The effect of implant-supported fixed prostheses on speech has been investigated objectively in a number of studies, but to date, no investigation has reported on the effect of implant-retained overdentures on the speech articulation. The aims of this study was to investigate if any change could be detected in speech with the transition from a conventional mandibular complete denture to an implant retained-overdenture, to examine if there was any correlation between mandibular denture stability and speech improvement.

5.3.2 Patient selection

Ten edentulous patients were selected from the waiting list of the Prosthodontic Department at Glasgow Dental Hospital. In order to obtain a relatively uniform grouping, the patients selected were female and over the age of 55. The age range was from 57 to 72 years (mean 66.3 years). The patients had been referred to the Department of Prosthodontic because of long-standing difficulties in coping with conventional dentures. These patients were provided with optimised conventional dentures, followed by implant treatment and the provision of implant-retained overdenture **(4.7.1)**. Speech assessment was carried out for this group of patients before and after implant treatment.

5.3.3 Speech recording

The first speech recording was carried out one week after the delivery of optimised conventional dentures. The second recording with the conventional dentures was carried out three weeks after the delivery and two weeks later the third recording was made. At the third session an additional recording was made for all patients without any dentures in place. The final recording for all patients was carried out after the implant-retained overdenture had been in function for three weeks. The recording procedures were as described in the maxillary overdenture study **(Section 5.2.4)**.

5.3.4 Audiological analysis

Audiological investigations were carried out in all patients using tuning fork with the use of both Rinnes' and Webers' tests. These are described in **Section 5.2.5**.

5.3.5 Objective assessment of speech by listening panel

The speech sounds were judged by two panels of listeners; an expert panel and a non-expert panel **(Section 5.2.6**.

6.3.5.1 Word-paired comparison test

From the assessments described in the first part of this chapter, the word-pair comparison test was used to detecting differences in speech occuring with I mplant treatment to provide stability for the mandibular dentures. The Kent word list was used in such away that each of the words were arranged in pairs consecutively in a database programme which was designed for the purpose of this study. For both the expert and the non-expert groups were asked to judge the speech on a five point scale **(Section 5.2.6.2)**.

5.3.6 RESULTS

5.3.6.1 Audiological analysis

Only three patients had normal hearing. Six patients exhibited mild hearing loss in either the left or the right side, indicating defective function of the outer or the middle ear. One patient appeared to have sensorineural hearing loss in the right ear.

5.3.6.2 Word-pairs comparison test

5.3.6.2.1 Statistical analysis

In this study, there was a restricted scale of measurement of five units (1-5) and a non-normal distribution of data. The Wilcoxon signed ranks test was used to test for significant differences in speech clarity for the group of ten patients, articulating each word in the Kent word list before and after implant treatment. Comparison with the implant-retained overdenture was carried out using the third recording session with the optimised conventional complete denture. This allowed the patients a five week interval to accommodate to the conventional denture.

Ten edentulous female subjects over the age of 55 were evaluated, each subject having had two ITI implants placed in anterior mandible to stabilise the mandibular complete denture. Each subject read 70 words from the Kent word-list before and after implant treatment but, due to problems in data transfer, only 62 words were recorded for all patients before and after implant treatment. Analysis was based on this 62 word sample from the Kent list.

Speech quality before and after treatment was analysed by 3 non-expert listeners and 3 expert listeners. The word-pairs (before and after treatment) were presented to the listeners in a random manner and the listeners did not know which sample was recorded before treatment and which was recorded after. The task of both the non-expert and expert was to identify which word was clearer.

A total of 620 word-pairs were analysed by each listener (10 subjects - 62 word-pairs each). Thereafter, the database programme converted the randomised selection of word to the relevant scale as follows:

1. Before treatment- speech clearly better.
2. Before treatment- speech slightly better.
3. No difference in speech quality before and after treatment.
4. After treatment- speech slightly better.
5. After treatment- speech clearly better.

To test the degree of agreement between the individual members of the panel on the effect of implant treatment on the quality of speech, comparison was carried out using the KAPPA values **(Section 5.2.6.3)**. The level of significance was tested at $P \leq 0.05$.

5.3.6.3 Agreement between Experts panel

It is clear from **Table 5.23** that the three expert listeners appeared to use the 1 to 5 scale in different ways. **Expert 3** used the extremes of the scale to a greater extent than the other two listeners. The assessments of **Expert 1** were concentrated to some extent in the middle category as were the judgements of **Expert 2**. **Expert 3** found the clarity of speech was affected by implant treatment in 80% of the tested words, **Expert 1** found that 45.97% of the samples were affected by implant treatment, while **Expert 2** found that speech changes was evident in only 13.39% following implant treatment.

Expert No.1			**Expert No.2**			**Expert No.3**		
Scale	**Count**	**Percent**	**Scale**	**Count**	**Percent**	**Scale**	**Count**	**Percent**
1	99	15.97	1	5	0.81	1	259	41.77
2	58	9.35	2	24	3.87	2	19	3.06
3	335	54.03	3	537	86.61	3	124	20.00
4	44	7.10	4	23	3.71	4	22	3.55
5	84	13.55	5	31	5.00	5	196	31.61
N	**620**	100	**N**	**620**	100	**N**	**620**	100

Table 5.23: Expert listeners, summary statistics:

Agreement between Expert 1 and Expert 2 (Table 5.24)

There was agreement between Experts 1 and 2 that in 306 of the 620 word pairs (49.35%) there was no appreciable change in speech quality after implant treatment, but there was little agreement about changes in speech quality induced following implant treatment. There was agreement in only one word-pair that speech was slightly clearer after implant treatment, and in 24 word-pairs these listeners agreed that speech was

clearly better after treatment. These experts agreed that speech was slightly clearer prior to implant treatment for 2 word-pairs and in only 2 pairs speech clarity was much better before treatment. The overall agreement between the two listeners was 54.02%, the greater part of this agreement being with respect to absence of change in speech clarity after implant treatment **(Table 5.24)**. The KAPPA value for all of the 620 words based on assessments of **Expert 1** and **Expert 2** was 0.112, indicating a low level of agreement.

Scale	1	2	3	4	5	**ALL**
1	**2** **0.32%**	7 1.13	83 13.39	6 0.97	1 0.16	99 15.97
2	0 --	**2** **0.32%**	53 8.55	3 0.48	0 --	58 9.35
3	2 0.32	14 2.26	**306** **49.35%**	9 1.45	4 0.65	335 54.03
4	1 0.16	1 0.16	39 6.29	**1** **0.16%**	2 0.32	44 7.10
5	0 --	0 --	56 9.03	4 0.65	**24** **3.87%**	84 13.55
ALL	5 0.81	24 3.87	537 86.61	23 3.71	31 5.00	**620** **100%**

Table 5.24: KAPPA assessment of **Experts 1 & 2** agreement in analysis of word pairs **Expert 1**-Columns. **Expert 2**-Rows.

Agreement between Expert 1 and Expert 3 (Table 5.25)

Expert 1 and **Expert 3** used the full range of the assessment scale to a greater degree than **Expert 2.** There was agreement with respect to lack of appreciable change in 89 word-pairs after implant treatment. These experts listeners agreed that speech was clearly better before implant treatment for 61 word-pairs, and slightly better before treatment in 3 word-pairs. There was agreement in only one word-pair that speech was slightly better after treatment and in 48 word-pairs these listeners agreed that speech was clearly better after implant treatment. There was overall agreement in 32.57% of the word-pairs **(Table 5.25)**. The KAPPA value (0.132), which was the highest found among three expert listeners, was low indicating poor level of agreement.

Scale	1	2	3	4	5	ALL
1	**61** **9.84%**	2 0.32	8 1,29	4 0.65	24 3.87	99 15.97
2	31 5.00	**3** **0.48%**	6 0.97	0 --	18 2.90	58 9.35
3	133 21.45	10 1.61	**89** **14.35%**	14 2.26	89 14.35	335 54.03
4	16 2.58	3 0.48	7 1.13	**1** **0.16%**	17 2.74	44 7.10
5	18 2.90	1 0.16	14 2.26	3 0.48	**48** **7.74%**	84 13.55
ALL	259 41.77	19 3.06	124 20.00	22 3.55	196 31.61	**620** **100%**

Table 5.25: KAPPA assessment of **Experts 1** and **3** agreement in analysis of word pairs. **Expert 1**-Columns. **Expert 3**-Rows.

Agreement between Expert 2 and Expert 3 (Table 5.26)

Expert 3 used the full range of the scale to a greater extent than **Expert 2**, the latter concentrated largely on the middle of the scale. There was agreement with respect to a lack of change in speech quality following implant treatment in 121 word-pairs (19.52%). There was an agreement that 4 word-pairs were clearly better before implant treatment, and a little better before treatment in 1 word-pair. In 2 word-pairs there was agreement that speech was a little clearer following implant treatment and in 29 word-pairs there were an agreement that speech was clearly better after treatment. The overall agreement between the two listeners was 25.33%. The KAPPA value was very low (0.072), indicating low level of agreement between these two expert listeners.

Scale	1	2	3	4	5	ALL
1	**4** **0.65%**	1 0.16	0 --	0 --	0 --	5 0.81
2	16 2.58	**1** **0.16%**	2 0.32	1 0.16	4 0.65	24 3.87
3	231 37.26	16 2.58	**121** **19.52%**	18 2.90	151 24.35	537 86.61
4	7 1.13	1 0.16	1 0.16	**2** **0.32%**	12 1.94	23 3.71
5	1 0.16	0 --	0 --	1 0.16	**29** **4.68%**	31 5.00
ALL	259 41.77	19 3.06	124 20.00	22 3.55	196 31.61	**620** **100%**

Table 5.26: KAPPA assessment of **Experts 1** and **3** agreement in analysis of word pairs. **Expert 2**-Columns. **Expert 3**-Rows.

The highest level of overall agreement (54.02%) was found between **Expert 1** and **Expert 2**. This occurred because both indicated that in a large proportion of instances there was no appreciable change in the clarity of speech associated with implant treatment.

5.3.6.4 Rating of changes in speech quality for each patient by Expert 1

In order to assess whether there were identified changes in speech quality after implant treatment for any of the patients on an individual basis, examination of speech assessment values for each patient was carried out. The findings for **Expert 1** are presented in **Table 5.27**.

Patient 1	Count	Percent
1	9	14.52
2	4	6.45
3	42	67.74
4	4	6.45
5	3	4.84
N	**62**	100

Patient 2	Count	Percent
1	18	29.03
2	8	12.90
3	25	40.32
4	5	8.06
5	6	9.68
N	**62**	

Patient 3	Count	Percent
1	9	14.52
2	5	8.06
3	38	61.29
4	5	8.06
5	5	8.06
N	**62**	100

Patient 4	Count	Percent
1	17	27.42
2	3	4.84
3	19	30.65
4	4	6.45
5	19	30.65
N	**62**	100

Patient 5	Count	Percent
1	7	11.29
2	6	9.68
3	37	59.68
4	7	11.29
5	5	8.06
N	**62**	100

Patient 6	Count	Percent
1	16	25.81
2	6	9.68
3	27	43.55
4	6	9.68
5	7	11.29
N	**62**	100

Patient 7	Count	Percent
1	5	8.06
2	10	16.13
3	42	67.74
4	3	4.84
5	2	3.23
N	**62**	100

Patient 8	Count	Percent
1	7	11.29
2	7	11.29
3	42	67.74
4	1	1.61
5	5	8.06
N	**62**	100

Patient 9	Count	Percent
1	2	3.23
2	2	2.23
3	30	48.39
4	3	4.84
5	25	40.32
N	**62**	100

Patient 10	Count	Percent
1	9	14.52
2	7	11.29
3	33	53.23
4	6	9.68
5	7	11.29
N	**62**	100

Table 5.27: Expert 1, ratings for each patient.

The Wilcoxon signed rank test was used to test the hypothesis that no change in speech was brought about by implant treatment. The null hypothesis that there was no change with implant treatment was rejected in favour of the hypothesis that the median was not 3 in those cases underlined in **Table 5.28** *($P \leq 0.05$)*. This analysis indicated that two patients showed statistically significant changes in speech quality following implant treatment as assessed by **Expert 1**. Patient No.2 showed significantly poorer speech after implant treatment, while patient No.9 showed a significant improvement after implant treatment. There were no other significant changes after implant treatment.

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	61.5	0.108	3.000
2	188.0	**0.014**	**2.500**
3	115.0	0.324	3.000
4	500.5	0.744	3.000
5	146.5	0.677	3.000
6	207.0	0.078	3.000
7	55.0	0.065	3.000
8	77.0	0.305	3.000
9	484.0	**0.000**	**4.000**
10	192.5	0.596	3.000

Table 5.28: Patient 1-10, analysis of **Expert 1**.

Rating of changes in speech quality for each patient by Expert 2

Speech assessment values for each patient on an individual basis, before and after implant treatment as estimated by **Expert 2** are presented in **Table 5.29**.

Patient 1	Count	Percent
1	3	4.84
2	8	12.90
3	51	82.26
4	0	0
5	0	0
N	62	100

Patient 2	Count	Percent
1	1	1.61
2	1	1.61
3	54	87.10
4	5	8.06
5	1	1.61
N	62	100

Patient 3	Count	Percent
1	0	0
2	0	0
3	58	93.55
4	3	4.84
5	1	1.61
N	62	100

Patient 4	Count	Percent
1	0	0
2	2	3.23
3	51	82.26
4	6	9.68
0	3	4.84
N	62	100

Patient 5	Count	Percent
1	0	0
2	1	1.61
3	57	91.94
4	4	6.45
5	0	0
N	62	100

Patient 6	Count	Percent
1	1	1.61
2	6	9.68
3	55	88.71
4	0	0
5	0	0
N	62	100

Patient 7	Count	Percent
1	0	0
2	5	8.06
3	57	91.94
4	0	0
5	0	0
N	62	100

Patient 8	Count	Percent
1	0	0
2	0	0
3	58	93.55
4	3	4.84
5	1	1.61
N	62	100

Patient 9	Count	Percent
1	0	0
2	0	0
3	35	56.45
4	2	3.23
5	25	40.32
N	62	100

Patient 10	Count	Percent
1	0	0
2	1	8.06
3	61	91.94
4	0	0
5	0	0
N	62	100

Table 1.29: Expert 2, ratings for each patient.

Patient No.9 showed a significant improvement in speech quality after implant treatment, but there was no other significant change for the other patients **(Table 5.30).**

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	0.0	0.004	3.000
2	25.0	0.363	3.000
3	10.0	0.100	3.000
4	57.0	0.037	3.000
5	12.0	0.281	3.000
6	0.0	0.022	3.000
7	0.0	0.059	3.000
8	10.0	0.100	3.000
9	378.0	**0.000**	**4.000**
10	0.0	1.000	3.000

Table 5.30: Patient 1-10, analysis of **Expert 2.**

Rating of changes in speech quality for each patient by Expert 3

Speech assessment values for each patient before and after treatment for **Expert 3** are presented in **Table 5.31**.

Patient 1	Count	Percent
1	18	29.03
2	3	4.84
3	32	51.61
4	3	4.84
5	6	9.68
N	**62**	100

Patient 2	Count	Percent
1	20	32.26
2	3	4.84
3	18	29.03
4	4	6.45
5	17	27.42
N	**62**	100

Patient 3	Count	Percent
1	19	30.65
2	2	3.23
3	15	24.19
4	2	3.23
5	24	38.71
N	**62**	100

Patient 4	Count	Percent
1	21	33.87
2	0	0
3	7	11.29
4	4	6.45
5	34	54.84
N	**62**	100

Patient 5	Count	Percent
1	18	29.03
2	0	0
3	7	11.29
4	1	1.61
5	36	58.06
N	**62**	100

Patient 6	Count	Percent
1	35	56.45
2	2	3.23
3	7	11.29
4	2	3.23
5	16	25.81
N	**62**	100

Patient 7	Count	Percent
1	39	62.90
2	1	1.61
3	9	14.52
4	2	3.23
5	11	17.74
N	**62**	100

Patient 8	Count	Percent
1	43	69.35
2	4	6.45
3	9	14.52
4	1	1.61
5	5	8.06
N	**62**	100

Patient 9	Count	Percent
1	16	25.81
2	0	0
3	8	12.90
4	2	3.23
5	36	58.06
N	**62**	100

Patient 10	Count	Percent
1	30	48.39
2	4	6.45
3	16	25.81
4	1	1.61
5	11	17.74
N	**62**	100

Table 5.31: Expert 3, ratings for each patient.

The Wilcoxon test showed that five patients exhibited statistically significant changes in speech quality after implant treatment. Patients Nos. 6,7,8, and 10 showed significantly poorer speech after implant treatment, and patient No.9 showed significantly improved speech following implant treatment. The remaining patients showed no significant change after treatment according to the assessment of the Expert 3 **(Table 5.32).**

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	121.5	0.023	3.000
2	458.0	0.670	3.000
3	629.0	0.495	3.000
4	1098.0	0.109	3.000
5	1027.0	0.032	3.000
6	485.0	**0.017**	**2.500**
7	317.5	**0.000**	**2.000**
8	150.5	**0.000**	**1.500**
9	1029.0	**0.014**	**4.000**
10	289.0	**0.006**	**2.000**

Table 5.32: Patient 1-10, analysis of **Expert 3**.

In summary, overall assessment by the three expert listeners showed that five patients were judged to have poorer speech after implant treatment by at least one listener from the expert panel, although in no case did more than one listener suggest that any patients speech was worse after implant treatment that it was before treatment. One patient (No.9) was judged to have an improvement in speech quality after implant treatment by all three experts.

5.3.6.5 Agreement between Non-Experts

From **Table 5.33** again it is clear that the three non-expert listeners used the 1 to 5 scale in different ways from each other. **Non-Expert 1** found the incidence of change in the speech quality was relatively high, indicating that 91.61% of words were affected by implant treatment. **Non-Expert 2** found a moderate proportion 65.97% of the tested words were affected by implant treatment and **Non-Expert 3** found that the speech quality was affected by implant treatment in 49.03% of words. It is clear from the summary data **(Table 5.33)** that **Non-Expert 1** used the extremes of the scale to a greater extent than the other two listeners.

Non-Expert No.1			Non-Expert No.2			Non-Expert No.3		
Scale	**Count**	**Percent**	**Scale**	**Count**	**Percent**	**Scale**	**Count**	**Percent**
1	172	27.74	1	148	23.87	1	24	3.87
2	43	6.94	2	134	21.61	2	94	15.16
3	52	8.39	3	211	34.03	3	316	50.97
4	55	8.87	4	55	8.87	4	137	22.10
5	298	48.06	5	72	11.61	5	49	7.90
N	**620**	100	**N**	**620**	100	**N**	**620**	100

Table 5.33: Non-Experts, summary statistics

Agreement between Non-Expert 1 and Non-Expert 2 (Table 5.34)

There was agreement between **Non-Expert 1** and **Non-Expert 2** with respect to there being an higher degree of speech clarity prior to implant treatment in 49 (7.90%) word-pairs. These non-expert listeners agreed that speech was clearly better before implant treatment for 12 word-pairs, and in 22 word-pairs they agreed that speech was not influenced by implant treatment. There was agreement in only four word-pairs that speech was slightly better after treatment and in 33 word-pairs these listeners agreed that speech was clearly better after implant treatment. The overall agreement between the two listeners was 19.36%, the greater part of this agreement being with respect to there being better speech before implant treatment was undertaken. The KAPPA value was 0.024, indicating low level of agreement between the two non-expert listeners.

Scale	1	2	3	4	5	**ALL**
1	**49** **7.90%**	33 5.32	54 8.71	15 2.42	21 3.39	172 7.74
2	11 1.77	**12** **1.94%**	11 1.77	5 0.81	4 0.65	43 6.94
3	10 1.61	8 1.29	**22** **3.55%**	4 0.65	8 1.29	52 8.39
4	13 2.10	15 2.42	17 2.74	**4** **0.65%**	6 0.97	55 8.87
5	65 10.48	66 10.65	107 17.26	27 4.35	**33** **5.32%**	298 48.06
ALL	148 23.87	134 21.61	211 34.03	55 8.87	72 11.61	**620** **100%**

Table 5.34: KAPPA assessment of **Non-Experts 1** and **2** agreement of analysis of word pairs. **Non-Expert 1**-Columns. **Non-Expert 2**-Rows.

Agreement between Non-Expert 1 and Non-expert 3 (Table 5.35)

Non-Expert 1 used the assessment scale in both extremes more than **Non-Expert 3** who used mostly the middle of the scale. There was agreement with respect to there being no appreciable change with 31 word-pairs after implant treatment. There was agreement in 8 word-pairs that speech was slightly better after treatment and in 27 word-pairs these non-expert listeners agreed that speech was clearly better after implant treatment. In only 3 word-pairs did they agree that speech was slightly better before implant treatment, and in 8 word-pairs that speech was clearly better before treatment. The overall agreement between the two listeners was 12.41% of the word-pairs. The

KAPPA value was very low (0.003) indicating little agreement between the two listeners.

Scale	1	2	3	4	5	ALL
1	**8** **1.29%**	31 5.00	91 14.68	30 4.84	12 1.94	172 27.74
2	0 --	**3** **0.48%**	23 3.71	12 1.94	5 0.81	43 6.94
3	1 0.16	9 1.45	**31** **5.00%**	9 1.45	2 0.32	52 8.39
4	4 0.65	11 1.77	29 4.68	**8** **1.29%**	3 0.48	55 8.87
5	11 1.77	40 6.45	142 22.90	78 12.58	**27** **4.35%**	298 48.06
ALL	24 3.87	94 15.16	316 50.97	137 22.10	49 7.90	**620** **100%**

Table 5.35: KAPPA assessment of **Non-Experts 1** and **3** agreement in analysis of word pairs. **Non-Expert 1**-Columns. **Non-Expert 3**-Rows.

Agreement between Non-expert 2 and Non-Expert 3 (Table 5.36)

Both **Non-Expert 2** and **Non-Expert 3** used the assessment scale with more concentration in the middle of the scale. There was agreement with respect to no appreciable change being induced by implant treatment in 117 word-pairs (18.87%). There was agreement that speech quality was better before implant treatment in 9 word-pairs, and little better in 17 word-pairs before treatment. In 11 word-pairs there was agreement that speech was a little clearer after implant treatment and in 15 word pairs the non-experts agreed that speech was clearly better after implant treatment. The overall agreement between the two listeners was 27.25%. The Kappa value based on 62-word pairs for ten subjects was 0.037, indicating low agreement between the two listeners.

Scale	1	2	3	4	5	ALL
1	**9** **1.45%**	35 5.65	71 11.45	25 4.03	8 1.29	148 23.87
2	10 1.61	**17** **2.74%**	66 10.65	30 4.84	11 1.77	134 21.61
3	3 0.48	28 4.52	**117** **18.87%**	51 8.23	12 1.94	211 34.03
4	1 0.16	6 0.97	34 5.48	**11** **1.77%**	3 0.48	55 8.87
5	1 0.16	8 1.29	28 4.52	20 3.23	**15** **2.42%**	72 11.61
ALL	24 3.87	94 15.16	316 50.97	137 22.10	49 7.90	**620** **100%**

Table 5.36: KAPPA assessment of **Non-Experts 2** and **3** agreement in analysis of word pairs. **Non-Expert 2**-Columns. **Non-Expert 3**-Rows.

The highest level of overall agreement (27.25%) was found between **Non-expert 2** and **Non-Expert 3** and this occurred because both listeners indicated that in a large proportion of instances there was no appreciable change in the clarity of speech associated with implant treatment.

5.3.6.7 Rating of changes in speech quality for each patient by Non-Expert1 (Table 5.37)

In order to assess whether there were indications of consistently identified changes in speech quality after implant treatment for any of the patients in the experimental group, examination of speech assessment values for each patient was carried out. The findings for **Non-Expert 1** are presented in **Table 5.37**.

Patient 1	Count	Percent
1	13	20.97
2	2	3.23
3	7	11.29
4	10	16.13
5	30	48.39
N	**62**	100

Patient 2	Count	Percent
1	13	20.97
2	1	1.61
3	1	1.61
4	7	11.29
5	40	64.52
N	**62**	100

Patient 3	Count	Percent
1	24	38.71
2	7	11.29
3	6	9.68
4	7	11.29
5	18	29.03
N	**62**	100

Patient 4	Count	Percent
1	20	32.26
2	5	8.06
3	7	11.29
4	8	12.90
5	22	35.48
N	**62**	100

Patient 5	Count	Percent
1	18	29.03
2	5	8.06
3	3	4.84
4	5	8.06
5	31	50.00
N	**62**	100

Patient 6	Count	Percent
1	12	19.35
2	5	8.06
3	4	6.45
4	7	11.29
5	34	54.84
N	**62**	100

Patient 7	Count	Percent
1	17	27.42
2	4	6.45
3	4	6.45
4	6	9.68
5	31	50.00
N	**62**	100

Patient 8	Count	Percent
1	19	30.65
2	4	6.45
3	11	17.74
4	3	4.84
5	25	40.32
N	**62**	100

Patient 9	Count	Percent
1	17	3.23
2	3	2.23
3	4	48.39
4	0	0
5	38	61.29
N	**62**	100

Patient 10	Count	Percent
1	19	30.65
2	7	11.29
3	5	8.06
4	2	3.23
5	29	46.77
N	**62**	100

Table 5.37 : Non-Expert 1, ratings for each patient

The Wilcoxon signed rank test was used to test the hypothesis that no change in speech was brought about by implant treatment. The null hypothesis that there was no change with implant treatment was rejected in favour of the hypothesis that the median was not 3 in those cases underlined in **Table 5.38** *($P \leq 0.05$).* The analysis indicated that four patients showed statistically significant changes in speech quality after implant treatment as assessed by **Non-Expert 1**. Patients No 1,2,6 and 9 showed a significant improvement after implant treatment. The other patients showed no significant changes after implant treatment according to the assessment of the Non-Expert 1.

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	1085.0	**0.008**	**4.000**
2	1431.5	**0.000**	**4.500**
3	691.5	0.387	3.000
4	815.0	0.709	3.000
5	1112.5	0.087	3.000
6	1252.5	**0.002**	**4.000**
7	1102.5	0.056	3.000
8	749.5	0.420	3.000
9	1178.0	**0.013**	**3.500**
10	981.0	0.220	3.000

Table 5.38: Patient 1-10, analysis of **Non-Expert 1**.

Rating of changes in speech quality for each patient by Non-Expert 2 (Table 5.39)

Speech assessment values for each patient before and after implant treatment as evaluated by **Non-Expert 2** are presented in **Table 5.39**.

Patient 1	Count	Percent
1	18	29.03
2	9	14.52
3	26	41.94
4	3	4.84
5	6	9.68
N	62	100

Patient 2	Count	Percent
1	6	29.68
2	21	33.87
3	26	41.94
4	6	9.68
5	3	4.84
N	62	100

Patient 3	Count	Percent
1	5	18.06
2	13	20.97
3	26	41.94
4	10	16.13
5	8	12.90
N	62	100

Patient 4	Count	Percent
1	14	22.58
2	17	27.42
3	14	22.58
4	9	14.52
5	8	12.90
N	62	100

Patient 5	Count	Percent
1	6	19.68
2	14	22.58
3	28	45.16
4	4	6.45
5	10	16.13
N	62	100

Patient 6	Count	Percent
1	24	38.71
2	16	25.81
3	13	20.97
4	8	12.90
5	1	1.61
N	62	100

Patient 7	Count	Percent
1	23	37.10
2	15	24.19
3	15	24.19
4	4	6.45
5	5	8.06
N	62	

Patient 8	Count	Percent
1	26	41.94
2	10	116.13
3	10	16.13
4	1	1.61
5	15	24.19
N	62	

Patient 9	Count	Percent
1	12	19.35
2	7	11.29
3	25	40.32
4	5	8.06
5	13	20.97
N	62	

Patient 10	Count	Percent
1	14	22.58
2	12	19.35
3	28	45.16
4	5	8.06
5	3	4.84
N	62	100

Table 5.39: Non-Expert 2, ratings for each patient

There were significant changes in speech quality after implant treatment evident in patients No. 1,2,6,7, and 10, who all showed significantly poorer speech quality after implant treatment. The remaining patients showed no significant changes **(Table 5.40).**

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	166.5	**0.009**	**2.500**
2	180.0	**0.017**	**2.500**
3	360.0	0.677	3.000
4	421.5	0.089	2.500
5	303.0	0.932	3.000
6	137.0	**0.000**	**2.000**
7	207.5	**0.000**	**2.000**
8	486.0	0.065	2.500
9	357.5	0.934	3.000
10	123.0	**0.003**	**2.500**

Table 5.40: Patient 1-10, analysis of **Non-Expert 2**.

Rating of changes in speech quality for each patient by Non-Expert 3 (Table 5.41)

Speech assessment values for each patient for before and after treatment, as assessed by **Non-Expert 3** are presented in **Table 1.41.**

Patient 1	Count	Percent
1	9	14.52
2	17	27.42
3	22	35.48
4	8	12.90
5	6	9.68
N	**62**	100

Patient 2	Count	Percent
1	4	6.45
2	10	16.13
3	28	45.16
4	10	16.13
5	10	16.13
N	**62**	100

Patient 3	Count	Percent
1	1	1.61
2	6	9.68
3	43	69.35
4	11	17.74
5	1	1.61
N	**62**	100

Patient 4	Count	Percent
1	2	3.23
2	13	20.97
3	22	35.48
4	21	33.87
5	4	6.45
N	**62**	

Patient 5	Count	Percent
1	2	3.23
2	9	14.52
3	26	41.94
4	21	33.87
5	4	6.45
N	**62**	

Patient 6	Count	Percent
1	3	4.84
2	10	16.13
3	28	45.16
4	21	33.87
5	0	0
N	**62**	

Patient 7	Count	Percent
1	0	0
2	13	20.97
3	43	69.35
4	6	9.68
5	0	0
N	**62**	100

Patient 8	Count	Percent
1	1	1.61
2	9	14.52
3	48	77.42
4	3	4.84
5	1	1.61
N	**62**	

Patient 9	Count	Percent
1	1	1.61
2	3	4.84
3	28	45.16
4	14	22.58
5	16	25.81
N	**62**	

Patient 10	Count	Percent
1	1	1.61
2	4	6.45
3	28	45.16
4	22	35.48
5	7	11.29
N	**62**	

Table 5.41: Non-Expert 3, ratings for each patient

The Wilcoxon test showed that three patients exhibited significant changes in speech clarity after implant treatment. Patients No. 5,9 and 10 all showed a significant improvement in speech quality. The remaining patients showed no significant changes after implant treatment **(Table 5.42).**

Patient No.	Wilcoxon statistic	P values	Estimated Median
1	302.0	0.148	2.500
2	380.0	0.161	3.000
3	117.5	0.376	3.000
4	517.5	0.150	3.000
5	459.5	**0.048**	**3.500**
6	336.0	0.516	3.000
7	60.0	0.165	3.000
8	33.0	0.233	3.000
9	542.0	**0.000**	**3.500**
10	510.5	**0.000**	**3.500**

Table 5.42: Patient 1-10, analysis of **Non-expert 3**.

In summary, the results of the overall assessment of the three non-expert listeners showed that five patients (Nos.1,2,6,7,10) were judged to have poorer speech after implant treatment by at least one listener from the non-expert panel. Two of the three non-experts agreed that patient No.9 showed significant improvement in speech clarity after implant treatment. Patients Nos. 3,4,8 showed no change in speech quality following implant treatment in the assessments of all three non-expert listeners.

The level of agreement between experts and non-experts (inter-judgement reliability) was obtained. The measurement of the intra-judgement reliability between the non-experts and the experts was based on all 62 word-pairs for the ten subjects. The findings of KAPPA analysis indicated very poor agreement between the members of the listening panels **(Table 5.43)**. The highest KAPPA value was reported between **Non-Expert 3** and **Expert 2** (0.152). This is a very level of agreement. The KAPPA values for agreement between the expert listeners were slightly higher (0.112, 0.132 and 0.072) than for the non-expert listeners (0.024, 0.003 and 0.037).

	Non-Exp.1	Non-Exp.2	Non-Exp.3	Expert 1	Expert 2	Expert 3
Non-Exp.1	--	--	--	--	--	--
Non-Exp.2	0.024	--	--	--	--	--
Non-Exp.3	0.003	0.037	--	--	--	--
Expert 1	0.025	0.042	0.112	--	--	--
Expert 2	0.009	0.036	**0.152**	0.112	--	--
Expert 3	0.023	0.119	0.060	0.132	0.072	--

Table 5.43: Kappa values for both non-experts and experts listeners for all subjects

5.3.7 DISCUSSION

It is apparent from the literature that tooth loss and replacement with dental prostheses may cause deterioration in some aspect of speech performance, particularly in the early stages following denture insertion. As previously mentioned, to date no investigation has reported on the effect of implant-retained overdentures on the speech mechanism. Therefore, the aim of this study was to investigate if any change could be detected in speech with the transition from a conventional mandibular complete denture to an implant retained-overdenture, to examine if there was any correlation between mandibular denture stability and speech improvement.

In this study, ten female patients were provided with optimised conventional dentures and a speech recording was made. Speech quality was assessed by expert and non-expert listeners to investigate whether there was a any difference in speech quality before and after implant treatment. The comparison test was carried out using 62 word-pairs for all patients.

An important finding was that both groups of listeners used the five-point scale in different ways from each other. All three expert listeners agreed that for the majority of the recorded words there was no appreciable change in speech clarity associated with implant treatment.

Only one patient was assessed as having improved speech after implant treatment, by all three expert listeners. Furthermore, five patients were assessed with poorer speech quality after implant treatment. Hearing impairment may have been an important factor in these patients, four had been assessed as having hearing problems. Lundqvist et al (1992 a,b) and Lundqvist (1993) reported that impaired hearing could be a factor leading to a deterioration in speech after full arch rehabilitation with implant-fixed bridges.

The non-expert listeners also used the scale in different ways from each other. All three non-experts agreed that in the majority of the recorded words there was no appreciable change in speech clarity associated with implant treatment and the highest level of overall agreement was found between non-experts 2 and 3. Only one patient was

assessed as having improved speech after implant treatment based on the assessment of two non-expert listeners. Comparing the KAPPA values obtained for the expert and the non-expert listeners, it is apparent that level of agreement between the expert listeners was slightly higher than between the non-expert listeners, although there was still only a very low agreement. Both expert and non-expert panels agreed that patient No. 9 was the only one who showed a significant improvement in speech quality following implant treatment. As the tested words, selected from Kent word-list, were recorded as single word samples with patients given the time to read each word on the computer screen, this might have been a factor limiting the discrepancies in speech before and after implant treatment.

5.3.8 GENERAL CONCLUSION AND RECOMMENDATIONS FOR FURTHER RESEARCH

The following conclusions could be drawn from this study:

Other than for one patient, there was no significant change in speech quality after patients were provided with a modified implant-retained overdenture in the maxillary arch. It accepted that more time to allow adaptation to the new prostheses
Other than for one patient again there was no significant change in speech clarity after patients were provided with the mandibular implant-retained overdenture.

The main conclusion from this work derives from the apparent differences in opinion offered by the members of the listening panels. this tends to throw doubts on the validity on the use of subjective speech assessment by such methods, and it appears that it is only obvious when there is a dramatic change in speech quality that there is agreement between listeners. This matter is worth further consideration.

A further point of interest is the contrast between the apparent lack of change in speech quality noted by the listeners, and the ver positive view offered by the patient self-assessment data. It is recommended that speech assessment by listening panel is used with caution, and it is noted that the methods used in this study do not appear to offer a useful method of assessing outcome following the implant treatment described.

CHAPTER SIX

ASSESSMENT OF OUTCOME FOLLOWING TREATMENT OF EDENTULOUS PATIENTS WITH IMPLANT-RETAINED OVERDENTURES.

The introduction of osseointegrated dental implants has resulted in genuine advancements in prosthetic dentistry with significant functional and psychological benefits for patients who have had problems with conventional complete dentures.

There would be advantages, however, in being able to quantify in a meaningful way the clinical benefits arising from the use of implant-based prosthetic treatment. Despite reported improvements in oral function and in the psycho-social outlook of edentulous patients treated using dental implants, there is little published information describing the effective use of objective measures to define the presenting clinical problems or to allow a practical means of measuring treatment success. In Chapter Two the pitfalls of using psychometric analysis without broader dental assessment are seen, and the problems encountered when attempting to choose a practical and meaningful method of assessment are illustrated. Few published studies have used objective and subjective measures together in assessing the outcome of implant treatment, and in Chapters 3,4, and 5 it was considered meaningful to assess the effectiveness of implant treatment using a range of measures, to allow comparison between these methods.

The edentulous female patients had all been referred because of long-standing problems with their conventional dentures and most of these complaints were attributed to the loss of stability of the mandibular dentures in function. Prior to implant treatment, self-assessment of variables such as discomfort/pain, denture stability, speech, appearance, self-confidence, masticatory function and social interaction showed that a slight-to-moderate improvement could be achieved after patients had been provided with optimised conventional dentures. Exactly why such benefits occurred is not easily quantifiable. An important factor may have been that patients benefited from the design of these new dentures, which were constructed according to standard principles of

complete denture construction. Alternatively, changes in the dentist/patient relationship may have had the major influence.

With complete denture construction, as with many forms of dental treatment, the degree of clinical success, and the reasons for that success, are difficult to quantify. This is well illustrated in the many studies which have been conducted to investigate the relationship between the quality of dentures and improvements in oral function, often no close correlation between these two variables can be demonstrated. Nonetheless, several studies have concluded that edentulous individuals are severely handicapped with respect to masticatory function and that even clinically satisfactory or optimally constructed complete dentures are poor substitutes for the natural teeth.

In the present study, following implant treatment and after patients had been provided with implant-retained overdentures they assessed their own masticatory function in a very favourable light. These findings again bring us to the necessity of investigating, in functional terms, how great any improvement was and the causes of this apparently dramatic improvement in function.

A number of factors might have been important:

1) An improvement in the stability of the mandibular denture, provided by implant fixtures, may have had the effect of reducing pain, which in turn will have led to enhanced masticatory function, speech, comfort, aesthetics, self-confidence and social interaction.

2) The psychological effect may have been important, with an increased perception of the implant-retained overdenture as an integral part of their bodies, changing the outlook of the patients in a more general way and producing a more positive self-image.

3) Or there may be have been an element of bias, related to the patients' gratitude to the dental team. There is a large element of patient management incorporated into all successful treatment of the edentulous patient and in this clinical study, successful patient management in combination with the application of what was perceived as high quality dental care will have created a very positive impression.

Some of these issues were examined in the functional assessments undertaken in this work. When objective measurement of maximum bite force was undertaken, it was clear that there was a statistically significant improvement after implant treatment. This coincided with a perceived improvement in masticatory function as evaluated subjectively by means of self-administered questionnaires. Thus, these results showed a strong correlation between subjective and objective measures in this group of patients with respect to this masticatory function.

A different picture emerges when speech is considered. After implant treatment, the patients reported a considerable improvement in the quality of speech and with co-related self-confidence. However, objective speech assessment failed to provide any indication of this apparently important and improved dental function. In view of the common use of listening-panel assessments, and the widely held perception that dentures and speech quality are closely inter-related, this was somewhat surprising. It seems likely that the Kent word-list may be an inappropriate measure of this aspects of denture function, although the high incidence of hearing impairment may have played some part in the findings.

Measurement of treatment outcome with oral implants does not depend solely on clinical results even if the published criteria for clinical success with dental implants are meet; the social and psychological effects of treatment are also important. It was observed that the majority of patients in this study reported a remarkable improvement in self-confidence, psychological security and social interaction after implant-treatment, from the use of self-assessment questionnaires. On the other hand, the results of psychological tests used in this study showed little or no change in the patients' psychological status before and after implant treatment. Although the use of psychometric testing requires the services of a psychologist, the tests themselves are simple and convenient to administer. It is worthwhile considering why the measures used did not deliver clinically applicable findings.

The Symptom Check-List-90-R test deals with many different aspects of health and psychological distress, but the instructions restrict the respondent to indicating whether

these problems have distressed or bothered him/her within the previous seven days. This limitation is counterbalanced by the need to have a measure of psychological state which is sensitive to change in outlook, in this case hopefully induced by improved dental function. It seems that the major difficulty in using suitable sensitive measures is that these will also reflect changes in state induced by other life events. The use of other psychological tests in conjunction with objective dental function measures and self-assessment questionnaires would seem to offer scope for further investigation, but the problems arising from the effect of other life events are not likely to be easily overcome.

It is a major consideration that any appropriate psychological measure must be effective in distinguishing between satisfied and dissatisfied patients in the dental context. Based on the findings of this study, it seems that few patients were in psychological distress and this may have been a reason why little change was observed in patients' psychological outlook with treatment. For this reason, there may be a advantages from an experimental standpoint to alter the criteria for patient selection for implant treatment. It may be the case that patients suffering real psychological distress which can be ascribed to their dentures, would show real psychological benefits.

In broad term the following conclusions can be drawn from the findings of this study:

1) It was apparent from the self-assessment questionnaires that the implant-retained overdentures improved the subjects' level of masticatory function, comfort, self-confidence, speech, aesthetics, social interaction and overall satisfaction.
2) The objective measure of bite force generation showed there was a substantial improvement following implant treatment, and there was a positive correlation between the subjective and the objective measures with respect to this aspect of masticatory function.

3) Little or no change in speech quality was recorded after implant treatment, when speech was assessed by perceptual analysis. This was despite the fact that all patients reported a remarkable improvement in speech quality after implant treatment.

4) There was little overall change the in patients' psychological profiles before and after implant treatment. However, there were several interesting individual changes, which appear to suggest that life events are the overriding factor of importance in this form of objective analysis.

There were many interesting aspects to this research, which would be worthy of further development by continuing the investigations to include a larger experimental group. The main developments in terms of experimental technique that would seem appropriate would be the consideration of a conversational speech test and the consideration of the use of a wider barrage of psychological assessments.

A final suggestion for further research, it would be my view that the group of ten patients described in this work should be subject to continuing assessment over the coming years, not least because this would give a legacy to my time and efforts in Glasgow.

APPENDICES

Appendix 2.1: The Cattell's 16-PF Questionnaire. (Form C)

1

I think my memory is better than it ever was.

a. yes,
b. in between,
c. no.

2

I could happily live alone, far from anyone, like a hermit.

a. yes,
b. occasionally,
c. no.

3

If I say the sky is 'down' and winter is "hot", I would call a criminal:

a. a gangster,
b. a saint,
c. a cloud.

4

When going to bed, I:

a. drop off to sleep quickly,
b. in between,
c. have difficulty falling asleep.

5

When driving a car in a line of traffic, I feel satisfied:

a. to remain behind most of the other cars,
b. in between,
c. only after I've reached the front of the line.

6

At a party I let others keep the jokes and stories going.

a. yes,
b. sometimes,
c. no.

7

It's important to me not to live in messy surroundings.

a. true,
b. uncertain,
c. false.

8

Most people I meet at a party are undoubtedly glad to see me.

a. yes,
b. sometimes,
c. no.

9

I would rather exercise by:

a. fencing and dancing,
b. in between,
c. wrestling and cricket.

10

I smile to myself at the big difference between what people do and what they say they do.

a. yes,
b. occasionally,
c. no.

11

In reading about an accident I like to find out exactly how it happened.

a. always,
b. sometimes,
c. seldom.

12

When friends play a joke on me, I usually enjoy it as much as the others, without feeling at all upset.

a. true,
b. in between,
c. false.

13

When someone speaks angrily to me, I forget the matter quickly.

a. true,
b. uncertain,
c. false.

14

I like to 'dream up' new ways of doing things rather than to be a practical follower of well-tried ways.

a. true,
b. uncertain,
c. false.

15

When I plan something, I like to do so quite alone without *any* outside help.

a. yes,
b. occasionally,
c. no.

Go on to the next page

16

I consider myself less "highly strung" than most people.

a. true,
b. in between,
c. false.

17

I get impatient easily with people who don't decide quickly.

a. true,
b. in between,
c. false.

(End, column 1 on answer sheet.)

18

I have sometimes, even if briefly, had hateful feelings towards my parents.

a. yes.
b. in between,
c. no.

19

I would rather tell my innermost thoughts to:

a. my good friends,
b. uncertain,
c. a diary.

20

I think the opposite of the opposite of 'inexact' is:

a. casual,
b. accurate,
c. rough.

21

I always have lots of energy at times when I need it.

a. yes,
b. in between,
c. no.

22

I am more annoyed by a person who:

a. tells off-colour jokes and embarrasses people,
b. uncertain,
c. is late for an appointment and inconveniences me.

23

I greatly enjoy inviting guests and amusing them.

a. true,
b. uncertain,
c. false.

24

I feel that:

a. some jobs just don't have to be done as carefully as others,
b. in between,
c. any job should be done thoroughly if you do it at all.

25

I have always had to fight against being too shy.

a. yes,
b. in between,
c. no.

26

It would be more interesting to be:

a. a bishop,
b. uncertain,
c. a colonel.

27

If neighbours cheat me in small things, I would rather humour them than show them up.

a. yes,
b. occasionally,
c. no.

28

I like friends who:

a. are efficient and practical in their interests,
b. in between,
c. seriously think out their attitudes toward life.

29

It worries me if I hear others expressing ideas that are contrary to those that I firmly believe.

a. true,
b. in between,
c. false.

30

I am over-conscientious, worrying over my past acts or mistakes.

a. yes,
b. in between,
c. no.

Go on to the next page

31

If I were good at both, I would rather:

a. play chess,
b. in between,
c. go bowling.

32

I like to join people who show lively group enthusiasm.

a. yes,
b. in between,
c. no.

33

I put my faith more in:

a. insurance,
b. in between,
c. good fortune.

34

I can forget my worries and responsibilities whenever I need to.

a. yes,
b. sometimes,
c. no.

(End, column 2 on answer sheet.)

35

It's hard for me to admit when I'm wrong.

a. yes,
b. sometimes,
c. no.

36

In a factory it would be more interesting to be in charge of:

a. machinery or keeping records,
b. in between,
c. talking to and hiring new people.

37

Which word does not belong with the other two?

a. cat,
b. near,
c. sun.

38

Minor distractions seem:

a. to irritate me,
b. in between,
c. not to worry me at all.

39

I am quite happy to be waited on, at appropriate times, by personal servants.

a. often,
b. sometimes,
c. never.

40

I would rather live in a town:

a. artistically laid out, but relatively poor,
b. uncertain,
c. that is rough, prosperous, and booming.

41

People should insist more than they now do that moral laws be followed.

a. yes,
b. sometimes,
c. no.

42

I have been told that, as a child, I was rather:

a. quiet and kept to myself,
b. in between,
c. lively and always active.

43

I enjoy routine, constructive work, using a good piece of machinery or apparatus.

a. yes,
b. in between,
c. no.

44

I think most witnesses tell the truth even if it becomes embarrassing.

a. yes,
b. in between,
c. no.

45

When I meet new people I would rather:

a. discuss their politics and social views,
b. in between,
c. have them tell me some good, new jokes.

Go on to the next page

46

I try to make my laughter at jokes quieter than most people's.

a. yes,
b. in between,
c. no.

47

I never feel so wretched that I want to cry.

a. true,
b. uncertain,
c. false.

48

In music I enjoy:

a. military band marches,
b. uncertain,
c. violin solos.

49

I would rather spend two weeks in the summer:

a. bird-watching and walking in the country with a friend or two,
b. uncertain,
c. being a leader of a group in a camp.

50

The effort taken in planning ahead:

a. is never wasted,
b. in between,
c. is not worth it.

51

Inconsiderate acts or remarks by my neighbours do *not* make me touchy and unhappy.

a. true,
b. uncertain,
c. false.

(End, column 3 on answer sheet.)

52

When I know I'm doing the right thing, I find my task easy.

a. always,
b. sometimes,
c. seldom.

53

I would rather be:

a. in a business office, organizing and seeing people,
b. in between,
c. an architect, drawing plans in a quiet room.

54

'House' is to 'room' as 'tree' is to:

a. forest,
b. plant,
c. leaf.

55

Things go wrongs for me:

a. rarely,
b. occasionally,
c. frequently.

56

In most things in life, I believe in:

a. taking a gamble,
b. in between,
c. playing it safe.

57

Some people may think I talk too much.

a. likely,
b. uncertain,
c. unlikely,

58

I admire more:

a. a clever, but not dependable person,
b. in between,
c. a person who is average, but strong to resist temptations.

59

I make decisions:

a. faster than many people,
b. uncertain,
c. slower than most people.

60

I am more impressed by:

a. acts of skill and grace,
b. in between,
c. acts of strength and power.

Go on to the next page

61

I am considered a cooperative person.

a. yes,
b. in between,
c. no.

62

I enjoy talking more to polished, sophisticated people than with outspoken, down-to-earth individuals.

a. yes,
b. in between,
c. no.

63

I prefer to:

a. keep my problems to myself,
b. in between,
c. talk about them to my friends.

64

If a person doesn't answer when I make a suggestion, I feel I've said something silly.

a. true,
b. in between,
c. false.

65

I learned more in my school days by:

a. going to class,
b. in between,
c. reading books.

66

I avoid getting involved in social responsibilities and organizations.

a. true,
b. sometimes,
c. false.

67

When a problem gets hard and there is a lot to do, I try.

a. a different problem,
b. in between,
c. a different attack on the same problem.

68

I get strong emotional moods – anxiety, anger, laughter, etc. – that seem to arise without much actual cause.

a. yes,
b. occasionally,
c. no.

(End, column 4 on answer sheet.)

69

My mind doesn't work as clearly at some times as it does at others.

a. yes,
b. in between,
c. no.

70

I am happy to oblige people by making appointments at times they prefer, even if it is a bit inconvenient to me.

a. yes,
b. sometimes,
c. no.

71

I think the proper number to continue the series 1, 2, 3, 6, 5, is:

a. 10,
b. 5,
c. 7.

72

I have occasionally had a brief touch of faintness, dizziness, or light-headedness for no apparent reason.

a. yes,
b. uncertain,
c. no.

73

I would rather do without something than put a waiter or waitress to a lot of extra trouble.

a. yes,
b. occasionally,
c. no.

74

I live for the "here and now" more than most people do.

a. true,
b. uncertain,
c. false.

75

At a party, I like:

a. to get into worthwhile conversation,
b. in between,
c. to see people relax and completely let go.

Go on to the next page

76

I speak my mind no matter how many people are around.

a. yes,
b. sometimes,
c. no.

77

If I could go back in time, I'd rather meet:

a. Columbus,
b. uncertain,
c. Shakespeare.

78

I have to stop myself from getting too involved in trying to straighten out other people's problems.

a. yes,
b. sometimes,
c. no.

79

In a shop or supermarket, I would prefer to:

a. design and do window displays,
b. uncertain,
c. be a cashier.

80

If people think poorly of me, I can still go on calmly in my own mind.

a. yes,
b. in between,
c. no.

81

If an old friend seems cold and reserved to me, I usually:

a. just think they are in a bad mood,
b. uncertain,
c. worry about what I may have done wrong.

82

More trouble arises from people:

a. changing and meddling with ways that are, already satisfactory,
b. uncertain.
c. turning down new, promising methods.

83

I greatly enjoy talking to people about local problems.

a. yes,
b. sometimes,
c. no.

84

Prim, strict people don't seem to get along well with me.

a. true,
b. sometimes,
c. false.

85

I think I'm less irritable than most people.

a. true,
b. uncertain,
c. false.

(End, column 5 on answer sheet.)

86

I may be less considerate of other people than they are of me.

a. true,
b. sometimes,
c. false.

87

I would just as soon let someone else have all the worry of being in charge of an organization of which I am a member.

a. true,
b. uncertain,
c. false.

88

If the two hands on a watch come together exactly every 65 minutes (according to an accurate watch), the watch is running:

a. slow,
b. on time,
c. fast.

89

I am bored:

a. often,
b. occasionally,
c. seldom.

90

People say that I like to have things done my own way.

a. true,
b. occasionally,
c. false.

Go on to the next page

91

I find it wise to avoid too much excitement because it tends to wear me out.

a. yes,
b. occasionally,
c. no.

92

At home, with a bit of spare time, I:

a. use it chatting and relaxing,
b. in between,
c. arrange to fill it with special jobs.

93

I am shy, and careful, about making friendships with new people.

a. yes,
b. occasionally,
c. no.

94

I think that what people say in poetry could be put just as exactly in plain prose.

a. yes,
b. sometimes,
c. no.

95

I suspect that people who act friendly to me can be disloyal behind my back.

a. yes, generally,
b. occasionally,
c. no, rarely.

96

I think that even the most dramatic experiences during the year leave my personality much the same as it was.

a. yes,
b. sometimes,
c. no.

97

It would seem more interesting to be a:

a. naturalist and work with plants,
b. uncertain,
c. public accountant or insurance person.

98

I get unreasonable fears or distastes for some things, for example, particular animals, places and so on.

a. yes,
b. sometimes,
c. no.

99

I like to think out ways in which our world could be changed to improve it.

a. yes,
b. in between,
c. no.

100

I prefer games where:

a. you're in a team or have a partner,
b. uncertain,
c. each person is on their own.

101

At night I have rather fantastic or ridiculous dreams.

a. yes,
b. occasionally,
c. no.

102

If left in a lonely house I tend, after a time, to feel a bit anxious or fearful.

a. yes,
b. sometimes,
c. no.

(End, column 6 on answer sheet.)

103

I may deceive people by being friendly when I really dislike them.

a. yes,
b. sometimes,
c. no.

104

Which word does not belong with the other two?

a. think,
b. see,
c. hear.

105

If Mary's mother is Fred's father's sister, what relation is Fred to Mary's father?

a. cousin,
b. nephew,
c. uncle.

End of test.

Appendix 2.2: Symptom Check-List-90-R Questionnaire.

INSTRUCTIONS

Below is a list of problems people sometimes have. Please read each one carefully, and tick (√) the choice that best describes HOW MUCH THAT PROBLEM HAS DISTRESSED OR BOTHERED YOU DURING THE LAST SEVEN DAYS INCLUDING TODAY. Choose only one answer for each problem and do not skip any items, and if you have any questions please ask about them.

No.	NOT AT ALL	A LITTLE BIT	QUITE A BIT	MODERATELY	EXTREMELY	HOW MUCH WERE YOU DISTRESSED BY:
1)	0	1	3	2	4	Headaches
2)	0	1	3	2	4	Nervousness or shakiness inside
3)	0	1	3	2	4	Repeated unpleasant thoughts that won't leave your mind
4)	0	1	3	2	4	Faintness or dizziness
5)	0	1	3	2	4	Loss of sexual interest or pleasure
6)	0	1	3	2	4	Feeling critical of others
7)	0	1	3	2	4	The idea that someone else can control your thoughts
8)	0	1	3	2	4	Feeling others are to blame for most of your troubles
9)	0	1	3	2	4	Trouble remembering things
10)	0	1	3	2	4	Worried about sloppiness or carelessness
11)	0	1	3	2	4	Feeling easily annoyed or irritated
12)	0	1	3	2	4	Pains in heart or chest
13)	0	1	3	2	4	Feeling afraid in open spaces or in the streets
14)	0	1	3	2	4	Feeling low in energy or slowed down
15)	0	1	3	2	4	Thoughts of ending your life
16)	0	1	3	2	4	Hearing voices that others do not hear
17)	0	1	3	2	4	Trembling
18)	0	1	3	2	4	Feeling that most people can not be trusted
19)	0	1	3	2	4	Poor appetite
20)	0	1	3	2	4	Crying easily
21)	0	1	3	2	4	Feeling shy or uneasy with opposite sex
22)	0	1	3	2	4	Feelings of being trapped or caught
23)	0	1	3	2	4	Suddenly scared for no reason
24)	0	1	3	2	4	Temper outburst that you could not control
25)	0	1	3	2	4	Feeling afraid to go out of your house alone
26)	0	1	3	2	4	Blaming yourself for things
27)	0	1	3	2	4	Pains in lower back
28)	0	1	3	2	4	Feeling blocked in getting things done

29)	0	1	3	2	4	Feeling lonely
30)	0	1	3	2	4	Feeling blue
31)	0	1	3	2	4	Worrying too much about things
32)	0	1	3	2	4	Feeling no interest in things
33)	0	1	3	2	4	Feeling fearful
34)	0	1	3	2	4	Your feelings being easily hurt
35)	0	1	3	2	4	Other people being aware of your private thoughts
36)	0	1	3	2	4	Feeling others do not understand you or are unsympathetic
37)	0	1	3	2	4	Feeling that people are unfriendly or dislike you
38)	0	1	3	2	4	Having to do things very slowly to insure correctness
39)	0	1	3	2	4	Heart bounding or racing
40)	0	1	3	2	4	Nausea or upset stomach
41)	0	1	3	2	4	Feeling inferior to others
42)	0	1	3	2	4	Soreness of your muscles
43)	0	1	3	2	4	Feeling that you are watched or talked about by others
44)	0	1	3	2	4	Trouble falling asleep
45)	0	1	3	2	4	Having to check and double-check what you do
46)	0	1	3	2	4	Difficulty making decisions
47)	0	1	3	2	4	Feeling afraid to travel on buses, subways, or trains
48)	0	1	3	2	4	Trouble getting your breath
49)	0	1	3	2	4	Hot or cold spells
50)	0	1	3	2	4	Having to avoid certain things, places, or activities because they frighten you
51)	0	1	3	2	4	Your mind going blank
52)	0	1	3	2	4	Numbness or tingling in parts of your body
53)	0	1	3	2	4	A lump in your throat
54)	0	1	3	2	4	Feeling hopeless about the future
55)	0	1	3	2	4	Trouble concentrating
56)	0	1	3	2	4	Feeling weak in parts of your body
57)	0	1	3	2	4	Feeling tense or keyed up
58)	0	1	3	2	4	Heavy arms or legs
59)	0	1	3	2	4	Thoughts of death or dying
60)	0	1	3	2	4	Overeating
61)	0	1	3	2	4	Feeling uneasy when people are watching or talking about you
62)	0	1	3	2	4	Having thoughts that are not your own
63)	0	1	3	2	4	Having urges to beat, injure, or harm someone
64)	0	1	3	2	4	Awakening in the early morning
65)	0	1	3	2	4	Having to repeat the same actions such as touching, counting, or washing
66)	0	1	3	2	4	Sleep that is restless or disturbed
67)	0	1	3	2	4	Having urges to break or smash things
68)	0	1	3	2	4	Having ideas or beliefs that others do not share
69)	0	1	3	2	4	Feeling very self-conscious with others
70)	0	1	3	2	4	Feeling uneasy in crowds, such as shopping or at a movie
71)	0	1	3	2	4	Feeling everything is an effort
72)	0	1	3	2	4	Spells of terror or panic
73)	0	1	3	2	4	Feeling uncomfortable about eating or drinking in public
74)	0	1	3	2	4	Getting into frequent arguments

75)	0	1	3	2	4	Feeling nervous when you are left alone
76)	0	1	3	2	4	Others are not giving you proper credit for your achievements
77)	0	1	3	2	4	Feeling lonely even when you are with people
78)	0	1	3	2	4	Feeling so restless you couldn't sit still
79)	0	1	3	2	4	Feelings of worthlessness
80)	0	1	3	2	4	The feeling that something bad is going to happen to you
81)	0	1	3	2	4	Shouting or throwing things
82)	0	1	3	2	4	Feeling afraid you will faint in public
83)	0	1	3	2	4	Feeling that people will take advantage of you if you let them
84)	0	1	3	2	4	Having thoughts about sex that bother you a lot
85)	0	1	3	2	4	The idea that you should be punished for your sins
86)	0	1	3	2	4	Thoughts and images of frightening nature
87)	0	1	3	2	4	The idea that something serious is wrong with your body
88)	0	1	3	2	4	Never feeling close to another person
89)	0	1	3	2	4	Feelings of guilt
90)	0	1	3	2	4	The idea that something is wrong with your mind

Appendix 3.1: Dental Function Questionnaire No.1.
(Comparison between dentures worn at the time of original presentation to Glasgow Dental Hospital and optimised conventional dentures, provided within the Department of Prosthodontics.)

Q1: **Name**:
Age:

Q2: **Marital status**
- Married
- Single
- Divorced
- Separated
- Cohabiting
- Widowed

Q3: **Occupation:**
In employment
- Full-time
- Part-time
- Housewife
- Retired

Q4: **Educational Background:**

- School
- University
- College

Health

*Q5:*Do you have any serious illness (such as heart disease, diabetes or high blood pressure).
- **Yes**
- **No**

If yes, please state.....

*Q6:*At present, are you taking any tablets or pills (e.g. for blood pressure, nerves etc. ?.
- **Yes**
- **No**

If yes, please state.....

Dental Information

*Q7:*How long have you worn a denture in your upper jaw ?
- Less than 3 years
- 3-5 years
- 5-10 years
- More than 10 years

*Q8:*How long have you worn a denture in your lower jaw ?
- Less than 3 years
- 3-5 years
- 5-10 years
- More than 10 years

Q9: Including your present dentures, how many sets of dentures have you had?

Previous Dentures

Q10: Prior to being provided with your present denture, did you wear your previous upper denture:
- All the time
- Sometimes
- Never
- At all times, other than sleeping

Q11: Prior to being provided with your present dentures, did you wear your previous lower denture:
- All the time
- Sometimes
- Never
- At all times, other than sleeping

Q12: Prior to being provided with your present dentures, did you have problems/troubles with your dentures ?

a) Upper dentures:
- Significant problems
- Minor problems
- No problems

b) Lower dentures:
- Significant problems
- Minor problems
- No problems
-

*Q13:*Thinking about your previous dentures, would you describe them as;
a) Very comfortable
b) Comfortable
c) Neither comfortable/uncomfortable
d) Rather uncomfortable
e) Very uncomfortable

*Q14:*Thinking about your previous dentures, were you aware of them in your mouth?
a) Very rarely
b) Occasionally
c) Moderately often
d) Most of the time
e) All of the time

*Q15:*Thinking about your previous dentures, did you,
a) Chew well with them
b) Have occasional difficulty chewing
c) Have frequent difficulty chewing
d) Always have difficulty chewing
e) Remove them to chew food

*Q16:*Thinking about your previous dentures, how concerned were you that they might slip or fall out when you were eating;
a) Could not have been more concerned
b) Very concerned
c) Mildly concerned
d) Moderately unconcerned
e) Completely unconcerned

*Q17:*Thinking about your previous dentures, how concerned were you that they might slip or fall out when you were speaking;
a) Could not have been more concerned
b) Very concerned
c) Mildly concerned
d) Moderately unconcerned
e) Completely unconcerned

*Q18:*Thinking about your previous dentures,
a) They did not affect my speech
b) They occasionally made speaking difficult
c) They frequently caused difficulty with speech
d) They always caused difficulty with speech
e) They had to be removed in order to speak

*Q19:*Thinking about your previous dentures, did you refuse invitations to go for meals or to social functions
a) Never
b) Very rarely
c) Occasionally
d) Most of the time
e) On every occasion

Q20: Thinking about your previous dentures, which statement most closely applies to how they felt in your mouth?
a) Always like a foreign body
b) Usually like a foreign body
c) Usually like part of yourself
d) Always like part of yourself

*Q21:*Thinking about your previous dentures, how did they affect your self-confidence?
a) Very bad effect
b) Bad effect
c) No effect
d) Good effect
e) Very good effect

*Q22:*Which statement best describes your previous dentures?
a) They never caused pain
b) They occasionally caused pain
c) They frequently caused pain
d) They always caused pain

*Q23:*Thinking about your previous dentures, did you think that they made
a) A significant improvement to your appearance
b) Some improvement in your appearance
c) No difference to your appearance
d) Your appearance worse

Optimised conventional denture

*Q24:*Has the new denture made
a) No difference to your life
b) Little difference to your life
c) A moderate difference to your life
d) A significant difference to your life
e) Transformed your life

*Q25:*Thinking about your new denture,
which statement most closely applies to how it feels in your mouth?
a) Always like a foreign body
b) Usually like a foreign body
c) Usually like part of yourself
d) Always like part of yourself

Q26:With your new denture in place, do you feel
a) More secure than previously
b) No more or less secure than previously
c) Less secure than previously

*Q27:*In comparison with your previous denture, do you feel the new denture fits
a) Significantly less well
b) A little less well
c) Of equal stability
d) A little better
e) Significantly better

*Q28:*In comparison with your previous denture, do you feel that with the new denture, you can eat,
a) Much less well than before
b) A little less well than before
c) Much the same as before
d) A little better than before
e) Much better than before

Q29: When wearing the new denture,
a) You can eat what you like
b) You can eat most things
c) Your diet is quite restricted
d) Your diet is very restricted

Q30: How much difficulty do you have eating hard foods (like apples and nuts) with the new denture
a) No difficulty
b) A little difficulty
c) Much difficulty
d) Extreme difficulty

Q31: How much difficulty do you have in speaking with the new denture?
a) No difficulty
b) A little difficulty
c) Much difficulty
d) Extreme difficulty

Q32: Would you say that the new denture has made your social life,
a) Much better
b) A little better
c) No change
d) A little worse
e) Much worse

Q33: Has the new denture made you feel
a) Much less confident
b) A little less confident
c) Has not affected my confidence
d) A little more confident
e) Much more confident

*Q34:*Would you say that the new denture has made your appearance,
a) Much better
b) A little better
c) No change
d) Little worse
e) Much worse

Q35: Does your new complete denture cause you
a) No problems
b) Some small problems
c) A number of problems
d)A great many problems

*Q36:*How self-conscious are you about the new denture?
a) Not at all
b) A little bit
c) Quite a lot
d) A very great deal

*Q37:*Do you wear your new upper denture:
a) All the time
b) Sometimes
c) Never
d) At all times, other than sleeping

*Q38:*Do you wear your new lower denture:
a) All the time
b) Sometimes
c) Never
d) At all times, other than sleeping

Q39: How satisfied are you with the new denture?
a) Not at all satisfied
b) A little bit satisfied
c) Very satisfied
d) Completely satisfied

Appendix 3.2: Dental Function Questionnaire No.2.
(Comparison between optimised complete denture and implant-retained overdenture.)

Optimised conventional denture

*Q1:*Prior to being provided with your implant-retained denture, did you previously wear your upper denture:
a)All the time
b)Sometimes
c)Never
d)At all times other than when sleeping

*Q2:*Prior to being provided with your implant-retained denture, did you previously wear your lower denture:
a)All the time
b)Sometimes
c)Never
d)At all times other than when sleeping

Q3:Prior to being provided with your implant-retained denture, did you have problems/troubles with your
a) Upper denture:
- Significant problems
- Minor problems
- No problems

b) Lower denture:
- Significant problems
- Minor problems
- No problems

Q4: Thinking about your previous (optimised) dentures, would you describe them as being;
a) Very comfortable
b) Comfortable
c) Neither comfortable/uncomfortable
d) Rather uncomfortable
e) Very uncomfortable

Q5: Thinking about your previous dentures (optimised), were you aware of them in your mouth ?
a) Very rarely
b) Occasionally
c) Moderately often
d) Most of the time
e) All of the time .

*Q6:*Thinking about your previous dentures (optimised), did you;
a) Chew well with them
b) Have occasional difficulty chewing
c) Have frequent difficulty chewing
d) Always have difficulty chewing
e) Remove them to chew food

Q7: Thinking about your previous dentures (optimised), how concerned were you that they might slip or fall out when you were eating;
a) Could not have been more concerned
b) Very concerned
c) Mildly concerned
d) Moderately unconcerned
e) Completely unconcerned

Q8: Thinking about your previous dentures (optimised), how concerned were you that they might slip or fall out when you were speaking;
a) Could not have been more concerned
b) Very concerned
c) Mildly concerned
d) Moderately unconcerned
e) Completely unconcerned

Q9: Thinking about your previous dentures (optimised),
a) They did not affect your speech
b) They occasionally made speaking difficult
c) They frequently caused difficulty with speech
d) They always caused difficulty with speech
e) They had to be removed to speak

Q10: Thinking about your previous dentures (optimised), did you refuse invitations to go for meals or to social functions'
a) Never
b) Very rarely
c) Occasionally
d) Most of the time
e) On every occasion

Q11: Thinking about your previous dentures (optimised), which statement most closely applies to how they felt in your mouth?
a) Always like a foreign body
b) Usually like a foreign body
c) Usually like part of yourself
d) Always like part of yourself

Q12: Thinking about your previous dentures (optimised) how did they affect your self-confidence?
a) Very bad effect
b) Bad effect
c) No effect
d) Good effect
e) Very good effect

*Q13:*Which statement best describes your previous (optimised) dentures.
a) They never caused pain
b) They occasionally caused pain
c) They frequently caused pain
d) They always caused pain

Q14: Thinking about your previous dentures (optimised), do you think they made,
a) A significant improvement to your appearance
b) Some improvement to your appearance
c) No difference to your appearance
d) Your appearance worse

Implant-retained overdenture

Q15: Has the implant-retained denture
a) Made no difference to your life
b) Made little difference to your life
c) Made a moderate difference to your life
d) Made a significant difference to your life
e) Transformed your life

Q16: Thinking about the implant-retained denture, which statement most closely applies to how it feels in your mouth?
a) Always like a foreign body
b) Usually like a foreign body
c) Usually like part of yourself
d) Always like part of yourself

Q17: With your implant-retained denture in place, do you feel?
a) More secure than previously
b) No more or less secure
c) Less secure than previously

Q18: In comparison with the previous denture (optimised), do you feel that the implant-retained denture fits?
a) Significantly less well
b) A little less well
c) Is of equal stability
d) A little better
e) Significantly better

Q19: In comparison with the previous denture (optimised), do you feel that with the implant-retained denture, you can eat?
a) Much less well than before
b) A little less well than before
c) Much the same as before
d) A little better than before
e) Much better than before

Q20: When wearing the implant-retained denture
a) You can eat what you like
b) You can eat most things
c) Your diet is quite restricted
d) Your diet is very restricted

Q21: How much difficulty do you have eating hard foods (like apples and nuts) with the implant-retained denture
a) No difficulty
b) A little difficulty
c) Much difficulty
d) Extreme difficulty

Q22: How much difficulty do you have in speaking with the implant-retained denture?
a) No difficulty
b) A little difficulty
c) Much difficulty
d) Extreme difficulty

Q23: Would you say that the implant-retained denture has made your social life?
a) Much better
b) A little better
c) No change
d) A little worse
e) Much worse

Q24: Has the implant-retained denture made you feel?
a) Much less confident
b) A little less confident
c) Has not affected my confident
d) A little more confident
e) Much more confident

Q25: Would you say that the implant-retained denture has made your appearance?
a) Much better
b) A little better
c) No change
d) A little worse
e) Much worse

Q26: Which statement best describes your implant-retained denture
a) It never causes pain
b) It occasionally causes pain
c) It frequently causes pain
d) It always causes pain

Q27: Thinking about your implant-retained denture, would you describe it as being,
a) Very comfortable
b) Comfortable
c) Neither comfortable/uncomfortable
d) Rather uncomfortable
e) Very uncomfortable

Q28: Does your implant-retained denture cause you?
a) No problems
b) Some small problems
c) A number of problems
d) A great many problems

*Q29:*How self-conscious are you about your implant-retained denture?
a) Not at all
b) A little bit
c) Quite a lot
d) A very great deal

Q30: Do you wear your present upper denture?
a) All the time
b) Sometimes
c) Never
d)All times other than when sleeping

Q31: Do you wear your present lower (implant) denture?
a) All the time
b) Sometimes
c) Never
d)All times other than when sleeping

Q32: If the clock were turned back, would you have the implant operation again?
a) Yes
b) Perhaps
c) No

Q33: Would you recommend a friend to have implants placed?
a) Yes
b) Perhaps
c) No

Q34: How satisfied are you with the implant-retained denture?
a) Not at all satisfied
b) A little bit satisfied
c) Very satisfied
d) Completely satisfied

Appendix 5.1: Kent words-list.

1	bad	**36**	Geese
2	sip	**37**	Chop
3	spit	**38**	Ship
4	knot	**39**	Feet
5	sigh	**40**	Coat
6	sheet	**41**	Dug
7	sticks	**42**	Cash
8	knew	**43**	Fill
9	leak	**44**	Hat
10	chair	**45**	Hold
11	nice	**46**	Heat
12	write	**47**	Bill
13	side	**48**	Ache
14	pat	**49**	Lip
15	hand	**50**	Reap
16	ate	**51**	Rise
17	witch	**52**	Row
18	much	**53**	Wax
19	sew	**54**	Dock
20	feed	**55**	Cheer
21	him	**56**	Hash
22	at	**57**	Tile
23	air	**58**	Bunch
24	pit	**59**	Ease
25	read	**60**	Seed
26	sell	**61**	Sink
27	blend	**62**	Harm
28	shoot	**63**	Cake
29	see	**64**	Meat
30	slip	**65**	Had
31	steak	**66**	Hail
32	blow	**67**	Hall
33	beat	**68**	Fork
34	sin	**69**	Rake
35	rock	**70**	Leak

Appendix 5.2: The words used in the intelligibility test, with the Kent word-list in bold and underlined.

1	bat	**bad**	bed	pad	**36**	goose	guess	**geese**	gas
2	ship	tip	**sip**	zip	**37**	chap	**chop**	shop	top
3	**spit**	pit	sit	it	**38**	sheep	dip	tip	**ship**
4	nod	**knot**	dot	nut	**39**	fit	heat	fat	**feet**
5	thigh	tie	shy	**sigh**	**40**	goat	**coat**	code	tote
6	**sheet**	seat	feet	eat	**41**	tug	**dug**	duck	bug
7	six	**sticks**	ticks	stick	**42**	**cash**	gash	duck	bug
8	know	knee	**knew**	gnaw	**43**	hill	pill	**fill**	full
9	reek	lick	league	**leak**	**44**	**hat**	fat	pat	that
10	share	**chair**	tear	air	**45**	old	**hold**	fold	cold
11	knife	night	**nice**	dice	**46**	eat	feet	hate	**heat**
12	white	ride	**write**	light	**47**	mill	dill	**bill**	gill
13	**side**	sign	sight	sigh	**48**	aches	ape	**ache**	ate
14	bat	**pat**	pot	pad	49	leap	lit	rip	**lip**
15	and	sand	fanned	**hand**	**50**	**reap**	rip	leap	weep
16	hate	**ate**	aid	fate	**51**	wise	lies	eyes	**rise**
17	**witch**	wish	rich	wit	**52**	**row**	woe	low	owe
18	**much**	mush	mut	muck	**53**	wack	**wax**	lax	racks
19	shoe	toe	**sew**	foe	**54**	docks	mock	knock	**dock**
20	food	feet	fee	**feed**	**55**	sheer	sear	**cheer**	tear
21	hem	**him**	ham	hum	**56**	hatch	**hash**	ash	dash
22	hat	fat	add	**at**	**57**	**tile**	dial	pile	mile
23	hair	fare	**air**	are	**58**	**bunch**	much	punch	bun
24	**pit**	pet	pat	bit	**59**	is	cheese	**ease**	peas
25	lead	**read**	weed	rid	**60**	see	**seed**	seeds	feed
26	tell	shell	fell	**sell**	**61**	sing	pink	**sink**	ink
27	bend	lend	end	**blend**	**62**	arm	charm	**harm**	farm
28	**shoot**	suit	sheet	shot	**63**	take	cakes	ache	**cake**

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