POST ORTHODONTIC TREATMENT OCCLUSIONS
OBJECTIVES AND SIMULATION OF TREATMENT
A STUDY OF CENTRIC STOPS

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The course and particularly the thesis has provided me with many ups and downs, enough to realise the truth in the saying "A little knowledge is a dangerous thing." That there is a great deal still to acquire is patently obvious, I feel much as Sir Isaac Newtown did when he said:-

"I don't know what I may seem to the world, but as to myself I seem to have been only like a boy playing on the seashore and diverting myself in now and then finding a smoother pebble or prettier shell than ordinary, whilst the great ocean of truth lay undiscovered before me."

Unfortunately one cannot help but think he was being unduly modest whereas for others such as I the quotation is quite apt.

Now to the thesis and to misquote C. Day Lewis when it came time to put pen to paper I asked the Prof (KG) as to how one goes about it, the reply came -

"Begin at the beginning, go to the end, and there stop - that is what Prof, our Ortho tutor told me when it was settled I should write the thesis. It sounds simple enough. But what was the beginning? Haven't you ever wondered about where things start?"

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INTRODUCTION

Aesthetics is often the main and occasionally the only criteria by which orthodontic treatment is judged. The literature has many references concerning the ideal positions of teeth, however little importance is given to the tooth contacts that eventuate. It is assumed on a number of occasions that settling will provide the best possible fit.

The aim of this thesis is to simulate orthodontic treatment on hypothetical patients and evaluate the tooth contacts which result from this treatment. Stylised tooth contacts have been produced for intact dentitions but in spite of an extensive search of the literature no patterns for extraction cases were found. The experiment, therefore, was to use "normal" teeth in wax malocclusions representing Class I, Class II Div 1, Class II Div 2 and Class III. Where it was indicated these were treated with extractions of premolar teeth. It was considered that the different mechanics and torque values of the anterior brackets may have dissimilar affects on the resultant occlusions. If this was the case it would be manifest in the resultant tooth contacts. Quantity and site of tooth contact was noted, quality was difficult to assess as one may move teeth to where one believes they belong but nature will place them where they best adapt to the needs of the stomatognathic system. This obviously could not be considered using an articulator and wax models.

CHAPTER 1: WHAT IS THE OCCLUSION TO THE ORTHODONTIST?

Occlusion is a word of Latin origin - *occludere* meaning "shutting up" or "the act of closure or state of being closed." Accordingly many writers have used the term occlusion to denote the normal closure of teeth. Stallard (1926) continued from that point and noted that these same writers were beginning to use the term "functional occlusion" and thus by inference that teeth lacked function in certain closures.

Articulation was thought to express "the relation of the maxillary and mandibular teeth when in functional contact during the activity of the mandible." Occlusion therefore in the strictest sense could be described as the static interrelation of the inclined planes of the opposing teeth when they are held together with the jaws closed.

In orthodontic diagnosis, tooth position and occlusion are analysed in relation to a static morphologic norm using the intercuspal position as reference, *i.e.* unmounted hand held casts in the position of maximal intercuspation. Perry (1969) was of the opinion that orthodontists should be striving for more than full occlusal interdigitation and treat the occlusion to a functional occlusion.

It was generally assumed by orthodontists that when the teeth were aligned and placed in good interdigitation, good function would follow. The prosthetic concept was of balanced occlusion and in time a third concept surfaced of dynamic individual occlusion - based on evaluation of the health and function of each individuals masticatory system. The dynamic and static position of the functioning mandible are primarily determined by six factors according to Slavicek, (1988):-

1. the functional program of the neuromuscular system and the influence of proprioceptivity.
2. the morphology of the hard and soft structures of the temporomandibular joints.
3. the morphology of the occlusal surfaces of teeth, the most dominant determinant of the mandibular position.
4. compromises necessitated by various skeletal patterns.
5. head posture and its relationship to the cervical spine which can be influenced by total body posture.
6. the limits of motion established by ligaments attached to the mandible.

The classic work by Angle (1907) and more recently by Andrews (1972) have established accepted criteria for the optimal (ideal) morphologic relationship of the human dentition. The optimal, or ideal functional occlusion type has not been so easily identified and has essentially eluded the dental profession (Tipton & Rinchuse 1991). Several functional occlusion types have been recognised and advocated, such as balanced occlusion, canine-protected occlusion, group function occlusion, attritional (flat plane) occlusion and biologic (multivaried) occlusion (Isaacson 1976). Apparently no single type of functional occlusion has been found to predominate in nature. D'Amico (1958), Ismail & Guevara (1974), Scaife & Holt (1969) all found a predominance of canine protected occlusion. Beyron (1964) and MacMillan (1930) found a predominance of group function. Youdelis & Mann (1965), Sadowsky & Polson

(1984), Rinchuse & Sassouni (1982) all found a high occurrence of balanced occlusion i.e. possessing bilateral non-working contacts.

When a patient is treated with a full banded orthodontic appliance one invariably expects changes to the occlusion. The angle of incisal guidance may be changed by correcting overbite and overjet characteristics. The relationships of all cusps to their opposing fossae and even the cant of the occlusal plane. An entirely new occlusion is being created for that patient. The degree of success in achieving the goals of functional occlusion will depend on such limiting factors as anatomic variations of tooth size and shape, skeletal jaw relationship, influence of musculature, and cooperation of the patient.

It is important for the orthodontist to know if a relationship exists between a static occlusion and a functional occlusion, as most direct their patient treatment towards a "normal" ideal static occlusion. To a gnathologist it is suggested that a malocclusion is a misarticulation; so it is possible to:-

1) establish a good anatomic occlusion and still have malarticulation.
2) have some degree of anatomical malocclusion and still have good articulation.

Rinchuse and Sassouni (1983) were of the opinion that static and functional occlusions are separate entities though they put forward the hypothesis that non-working or balancing contacts can predominate only in a population with ideal static interdigitation of the teeth free of the many interferences of malocclusion. Ramfjord and Ash (1983) agreed that the alleged close relationship between form and function of the dentition is not dependant on the common standards such as overbite and cusp fossa relationship. He makes an analogy with the nose pointing out that the external appearance of the nose is not related to its breathing potential and accordingly makes a strong recommendation the functional and aesthetic criteria should be considered separately.

Throughout the literature review much has been written on functional occlusion but as Roth (1981c) tells us the requirements for the natural dentition have been rather vague. Ideal tooth contacts have been described by a number of gnathologists, the examples cited later are those of Lucia (1969) for the "tooth to tooth "variation. Scharer (1967) points out the occlusal concepts are primarily based on clinical necessities and many times adapted to our clinical possibilities. Tooth to tooth contact requires a Class II molar relationship and despite Lucia's claim it is a more logical, more scientific, more practical may just be a reflection of clinical necessity. Roth (1976) points out the cusp-fossa arrangement is lacking in its ability to provide idealised anterior guidance and good aesthetics. This is due to the need of increasing the labioaxial inclination of the maxillary cuspids eliminating immediate disclusion. The other is "tooth to two tooth" the variation used is that of the University of North Carolina laboratory notes (1989). Stylised and ideal contacts as shown as produced by themselves and Ricketts (1978) who made a study of approximately 200 cases at his disposal. All ideal tooth contact patterns have been made with reference to a complete dentition (third molars excluded). Despite an exhaustive search no ideal contact pattern has been offered for orthodontic extraction cases. Roth (1981c) mentions that orthodontists have been criticised for extraction of teeth by gnathologists on the grounds that it made it impossible to produce a good functional occlusion. He tells us in the paper that it is possible to produce a good functional occlusion but neither documents the source of the criticism or the specific problems involved, nor does he provide proof for his statement that a good functional occlusion is possible.

There is general agreement that orthodontists need a rational concept of occlusion based on the biologic and skeletal limitations of the case in order to obtain a realistic and stable end result. Thus far, most clinicians restrict their ideal orthodontic treatment goals to aesthetics and the "appropriate" arrangement of the teeth and arches as dictated by static goals. Because of this Stockli (1981) states that orthodontists must accept the gnathological accusation that in many instances the orthodontic treatment result may be functionally detrimental even though it may be qualified as a morphological success. Orthodontists cannot adopt without restriction the gnathological concept of occlusion. As brilliant as its mechanistic and geometric construction may be, it cannot replace the physiologic orthodontic approach, which also respects the dynamics of growth. Nathan, Allan and Shore (1959) tell us placement of teeth must be evaluated in terms of their total integration with the masticatory organ which in turn functions as part of the stomatognathic system. Function is the purpose of all organs, no single part of the masticatory organ can assume total responsibility for the occlusion of the teeth.

The nature of tooth contacts which occur in centric closure and during eccentric movement of the mandible have been demonstrated to have a profound effect on the periodontium, muscles and temporomandibular joint according to Moller and Bakke

(1988). Logic then dictates that ideal contact patterns of teeth occurring in centric and during jaw movement should be thoroughly understood before one is able to diagnose and treat abnormal conditions. The meeting of the two disciplines of gnathology and orthodontics must surely be through tooth contacts yet neither has addressed the need for an 'ideal' or goal for tooth contact patterns in extraction treatments.

So in conclusion we read that occlusal stability ought to be one of the first goals of orthodontic therapy, unfortunately as we are all aware most treatment is done to make the teeth look like the "correct" textbook version of intercuspation. The results according to Dellinger (1978), Perry (1969), Roth (1976) find the results are inconsistent and occasionally cause tooth hypermobility, abrasion or temporomandibular disorders. Storey (1979) demonstrated that the occlusal interface is not determined by occlusal contacts alone, but also involves the anatomy of the joints, the limiting influence of the ligaments and the shape and orientation of the occlusal plane. These he stated were the passive factors. The active factors include the muscles and the reflex responses that arise in and around the teeth joints, muscles and mucosa. These factors have not been dealt with in this thesis and reference should be made to such texts as Ramfjord and Ash - Occlusion, or Klineberg - Occlusion: Principles and Assessment both covering the essentials comprehensively.

Weinberg and Lager (1980) emphasise the limitations in using a scientific method in clinical research. They tells us if we could follow a scientific method in the investigation of temporomandibular pain - dysfunction syndrome a simple cause and effect relationship may be demonstrated that would eliminate controversy and confusion. It should also provide an almost totally effective cure. However, the problem in human research is that we cannot isolate the variables as we can in test tube conditions. Empiricism according to Weinberg and Lager (1980) is the practice of relying on observations and experiment, especially in the natural sciences. So despite the obvious limitations in simulating orthodontic therapy and producing occlusal patterns to be assessed a decision was made to attempt to eliminate many of the variables associated with individual patients. The experiment has provided a reasonable platform from which to base further evaluations and demonstrated an effective if not ideal tooth contact pattern is a realistic goal for orthodontists.

CHAPTER 2: STATIC OCCLUSION

It is important for the orthodontist to know if a relationship exists between a static occlusion and a functional occlusion, as most direct their patient treatment towards a "normal" ideal static occlusion.

The accepted static normal has for many years been that described by Angle in 1900, in his paper "Treatment of malocclusion of teeth and fractures of the maxillae, Angle's system"; Proffit (1986) tells us he included the first clear and simple definition of normal occlusion in the natural dentition. The basis of Angle's classification was the relationship of the first molar teeth and the alignment (or lack of it) of the teeth relative to the line of occlusion. Since however, precisely defined relationships required a full complement of teeth in both arches, maintaining an intact dentition became an important goal of orthodontic treatment.

Angle's classification thus began with four groups:-

Normal occlusion Normal (Class I) molar relationship, teeth on line of occlusion.

Class I malocclusion Normal (Class I) molar relationship, teeth crowded, rotated, etc.

Class II malocclusion Lower molar distal to upper molar, relationship of other teeth to line of occlusion not specified.

Class III malocclusion Lower molar mesial to upper molar, relationship of other teeth to the line of occlusion not specified.

Although the Angle system was a great step forward it was recognised that it was still incomplete, and this led to a number of informal additions at later stages including descriptions of other teeth in the arch.

The next great step forward came with Andrews (1972) who introduced us to his "Six Keys", these were formulated originally from a study of 120 non-orthodontic normal models. These models were chosen between 1960 & 1964 on the following criteria:-

i) never had orthodontic treatment;

ii) the teeth were straight and pleasing in appearance;

iii) had a "bite" which looked generally correct;

iv) would not, in the opinion of Andrews, benefit from orthodontic treatment.

During the years 1965-1971 another 1,150 orthodontically treated cases were reviewed and studied in order to learn how important the findings of the above study (in which the "six keys" were formulated) were to orthodontic cases, and if one key were absent would it allow a prediction of other failings. As Andrews (1979) later writes "It seems evident that orthodontics, orthodontists, and patients all would benefit if treatment goals could be objectified."

The "six keys" are summarised as follows:-

KEY I - Molar relationship

A. The distal surface of the distobuccal cusp of the upper first permanent molar made contact, and occluded with, the mesial surface of the mesiobuccal cusp of the lower second molar.

B. The mesiobuccal cusp of the upper first permanent molar fell within the groove between the mesial and middle cusps of the lower first permanent molar.

C. The mesiolingual cusp of the upper first molar seated in the central fossa of the lower first molar.

D. The canines and premolars enjoy a cusp-embrasure relationship buccally, and a cusp-fossa relationship lingually. Figure 1.

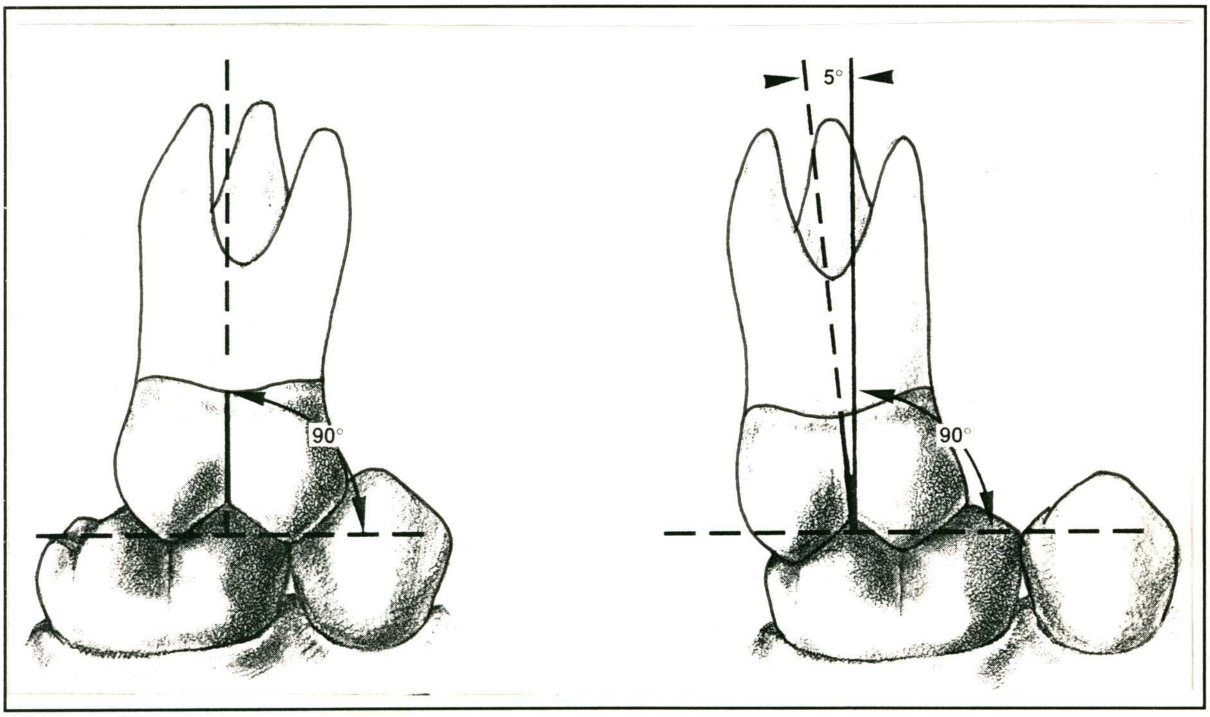


Figure 1

KEY II - Crown angulation

The gingival portion of the long axis of each crown is distal to the occlusal portion of that axis. Figure 2 and 3 show the average angulations of the upper teeth found in the non-orthodontic models. It appears that nature intends the upper teeth to occupy more room, via angulation, than the lower teeth. The degree of angulation of incisors determines the amount of mesiodistal space they occupy and, therefore has a considerable effect on posterior occlusion as well as anterior aesthetics.

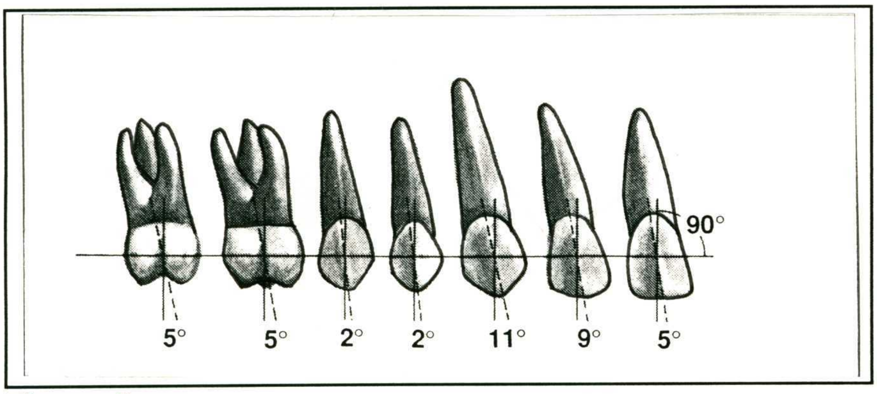


Figure 2

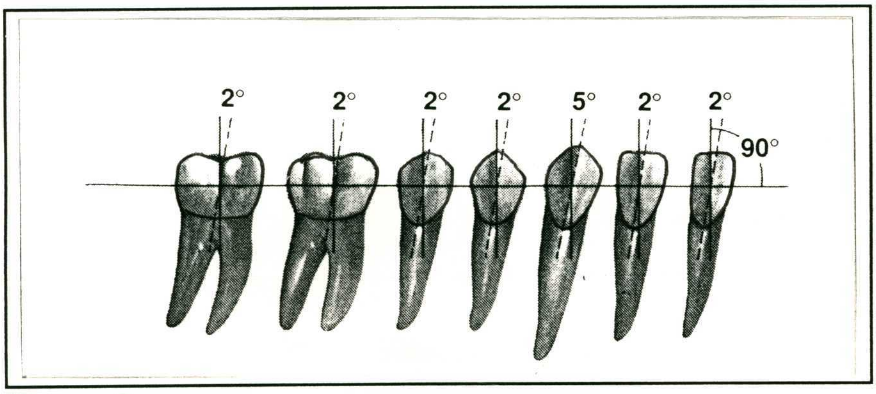
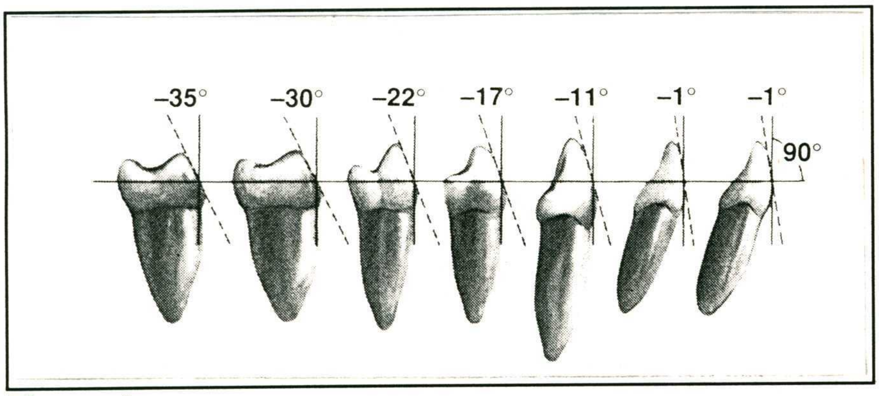


Figure 3

KEY III - Crown inclination

In upper incisors the gingival portion of the crown's labial surface is lingual to the incisal portion. In all other crowns, including lower incisors, the gingival portion of the labial or buccal surface is labial or buccal to the incisal labial or buccal portion Figures 4 and 5. In the upper arch the lingual crown inclination of the buccal surfaces is slightly more pronounced in the molars than it is in the canines and premolars Figure 6. In the lower canines, premolars, and molars, lingual crown inclination progressively increases. Figure 7.



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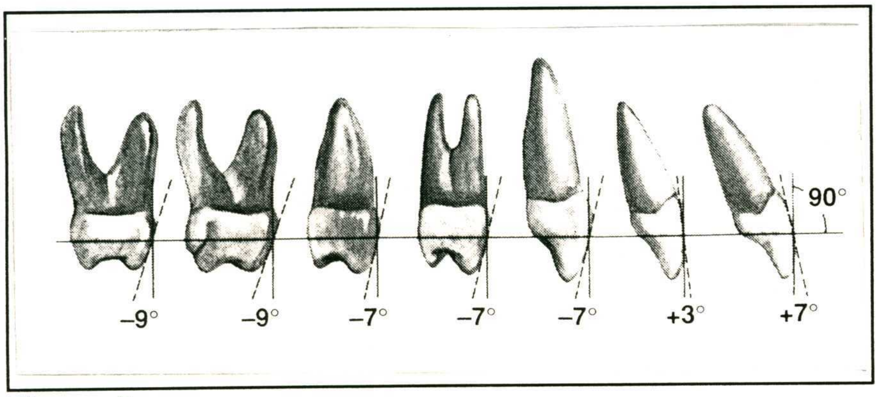

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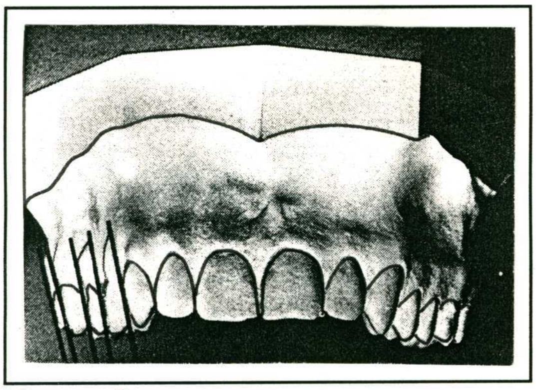

Figure 6

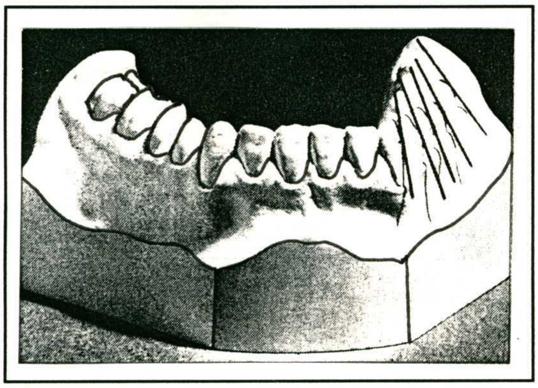

Figure 7

Nota Bene - If anterior crowns are insufficiently inclined as occasionally happens when the dental compensations for a skeletal discrepancy are too great, all upper contact points are too mesial preventing normal occlusion. Figure 8 and 9.

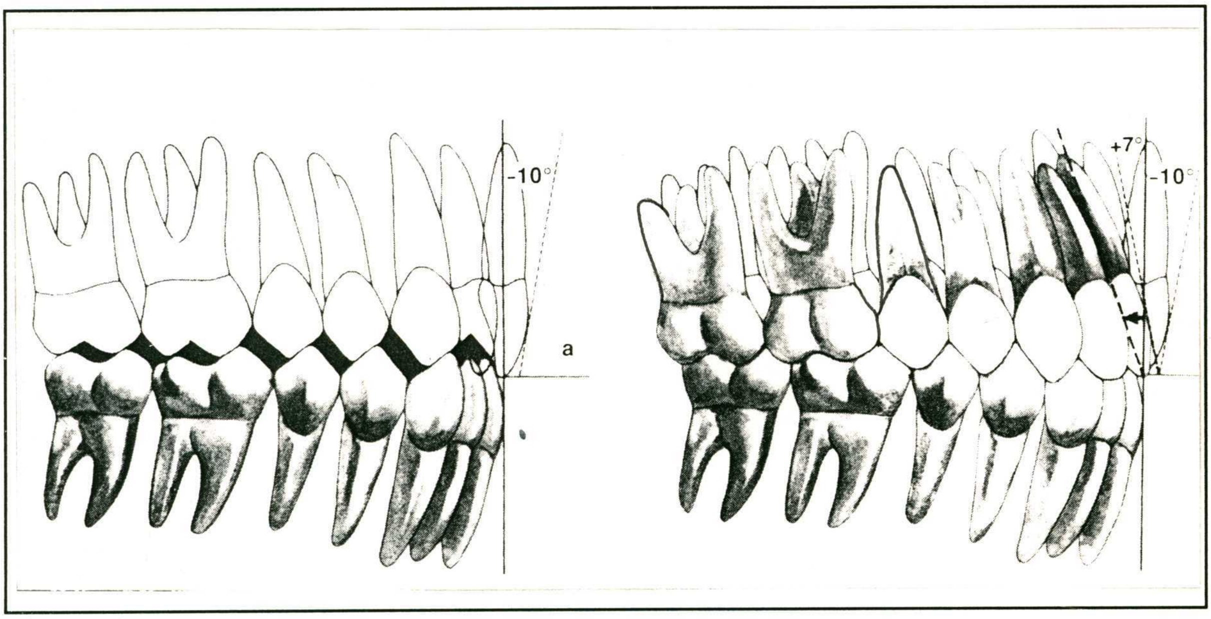

Figure 8

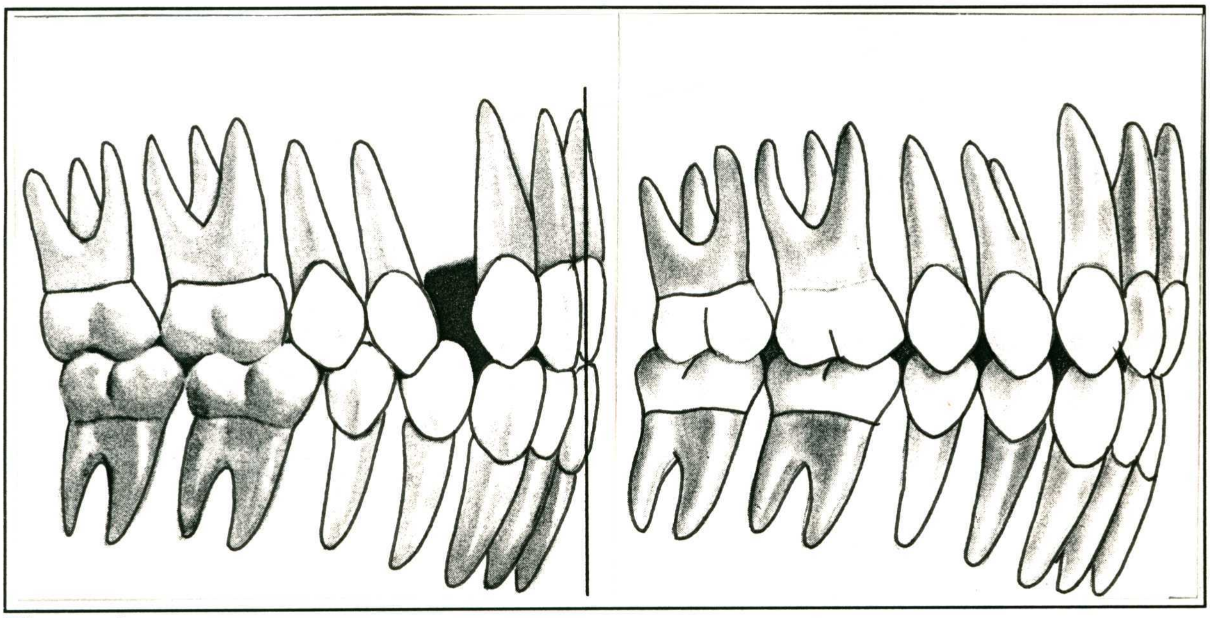

Figure 9

KEY IV - Rotations

Teeth should be free of undesirable rotations. A rotated molar or premolar occupies more space than it normally does, while a rotated incisor may occupy less space. Both of these types of rotations effect the position and occlusion of adjacent and other teeth. Figure 10.

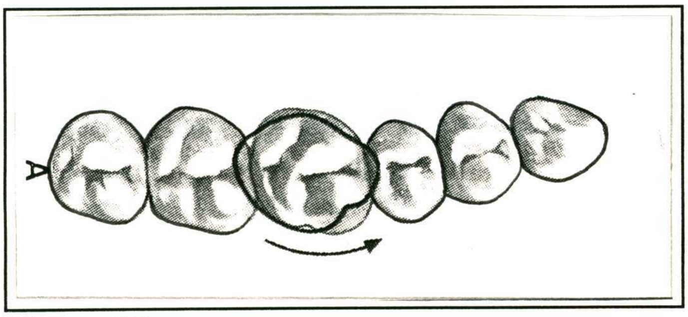

Figure 10

KEY V - Tight contacts

The contact points should be tight, although persons with genuine tooth-size discrepancies pose special problems.

KEY VI - Curve of Spee

The curve of Spee should have no more than a slight arc. The deepest curve of Spee in the non-orthodontic "normal" models were 1.5mm (from incisors to second molars). Figure 11.

It is interesting to note that the straight wire system did not really become accepted until Andrews work despite the fact Jarabak in the 1950's at Loyola University and Stone in the 1960's at Indiana University had both carried out extensive work on the concept. According to Bader (1991) the straight wire appliance by definition is designed to achieve Class I molar and Class I canine treatment objectives. Should one wish to produce a Class II molar and Class I canine relationship he suggests this is best achieved by a mesiolingual rotation of the maxillary first molars. This would suggest that compensation might equally be required in the various extraction patterns employed by orthodontists.

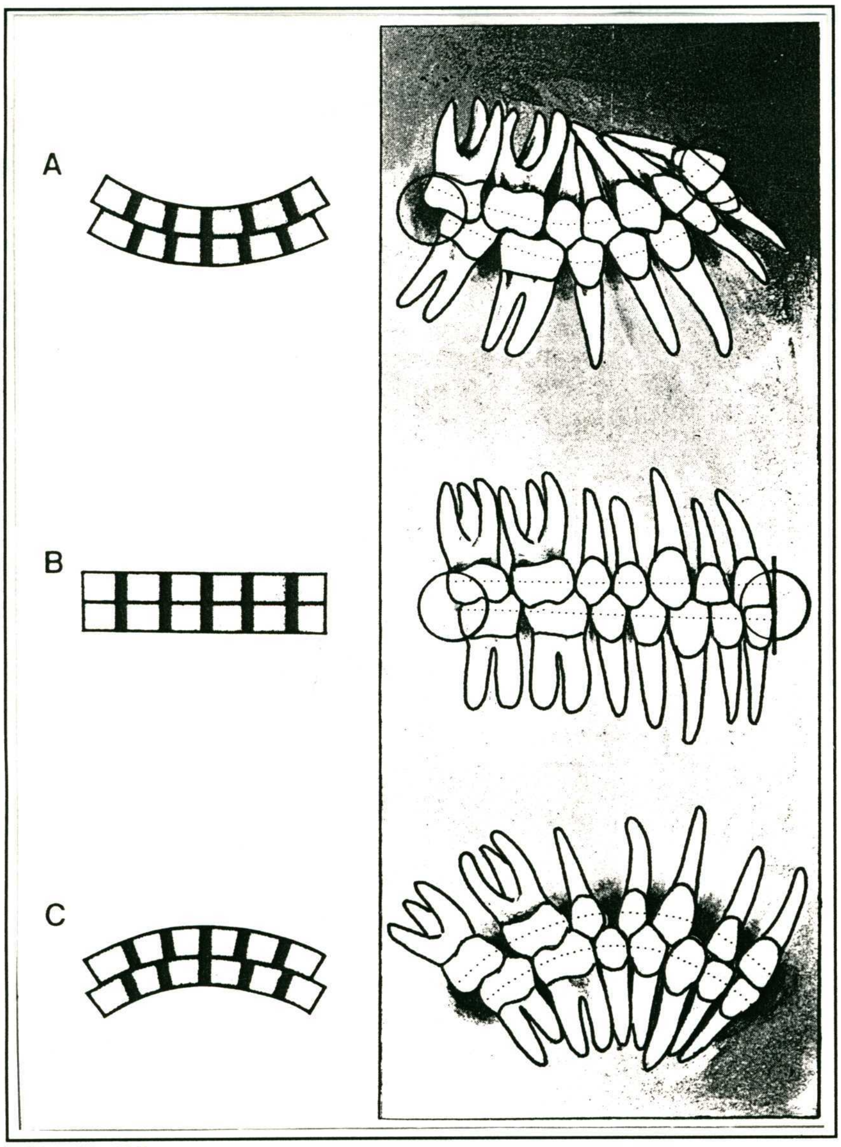

Figure 11

Andrews (1976) would have us believe that the standards used in evaluating and dictating static occlusion have been "authoritatively declared consistent with the requirements of functional occlusion." He quotes Roth 1975 (personal communication) as declaring "the six keys to be consistent with desirable functional occlusion goals, provided that the occlusal interdigitation occurs with the mandible in centric relation." Yet we find by reading Roth (1981c) that he states "if we meet orthodontic goals and achieve the static occlusion that is acceptable in the orthodontic speciality, we are automatically supposed to have created good occlusal function. Yet we know that this is not always, or even usually the case. We must set up the criteria for a good functioning occlusion and very carefully define the tooth arrangement necessary to meet these criteria." His statement is borne out by the research papers cited in Chapter 5.

CHAPTER 3: FUNCTIONAL, OR FUNCTIONING OCCLUSION

Bonwill in 1899 put forward the geometric and mechanical laws of articulation based on a balanced occlusion, "to bring into contact the largest amount of grinding surface of the bicuspids and molars, and, at the same time, to have the incisors all come into action during lateral movements." The resultant balanced occlusion would be for "equalising the action of muscles on both sides, simultaneously and getting the greatest amount of grinding surface at each movement." and in addition "to equalise the pressure and force on both sides or parts of the dental arches."Graf Von Spee (1890), Monson (1932) and Bonwill were all advocates of a geometric ideal and balanced occlusion. D'Amico (1960) pointed out much of Graf Von Spee's work was carried out on skulls showing extensive attrition of the occlusal surfaces of the teeth.

Walker (1896) designed an articulator with a condylar inclination to account for variables in the articular eminence. He was followed by Christensen in 1901 and Gysi 1910 who understood the morphological variation that we take for granted. The gnathologic concepts followed this path in 1926 with McCollum, gnathology was defined as the study and treatment of the entire dentition as a functioning unit. Particularly each tooth and its importance to the function of the entire system. Stallard and Atkinson were two orthodontists actively involved in the formative years of the Gnathological Society.

At about the same time Hellman (1921) proposed the concept of occlusion more as a biological or functioning entity. He rejected the idea of Angle's that an anatomically perfect relationship of teeth was essential for optimal functional capacity. He developed the concept that normal occlusion was that which was functionally adequate for the person concerned. He showed that deviations of up to 16% of the occlusal contacts described by Angle could be present in an occlusion and still an individual could have a "normal functioning" occlusion. That is, a person with an average or 90% perfect occlusion is a fair representation of good occlusion, and with a standard deviation of plus or minus 6% it would mean that those with 96% and 84% of the perfect occlusion should demonstrate it equally well.

Hellman used a group of relationships to define occlusion:

1. by surface contact
2. by point and fossa contact
3. by ridge and embrasure contact
4. by ridge and groove contact

From this he stated that there were 138 occlusal factors to consider in the make up of the adult dentition. Each factor being worth 0.8% of the perfect occlusion. For example he suggests if a dentition is found in normal occlusion with the incisors in an edge to edge relationship there is a loss of about 11 factors or 8%. In other words the dentition is only 92% perfect. He felt that one could use his system as a gauge to determine the need for orthodontic treatment.

Schuyler in 1929 began the functionalism concept of occlusion. He believed as did the gnathologists in harmony between centric relation and centric occlusion for the natural dentition. His description of occlusion was "such arrangements of the teeth as will provide the highest efficiency during all excursions of the mandible which are necessary to the function of mastication." Schuyler later suggested that with regard to balancing occlusion "that balancing contacts that may have appeared to be harmless may, with the unilateral application of force become traumatic, most destructive and extremely undesirable." *i.e.* a balancing contact may quite easily become an occlusal interference. Many orthodontists and gnathologists also subscribe to this point of view.

So the concept of mutual protection came about. It is based on the premise that the teeth should act as specialised groups so that in centric or eccentric positions of the mandible certain teeth or groups of teeth are best able to withstand the occlusal loads and, in doing so, will protect other teeth or groups of teeth from unfavourable forces. Stallard & Stuart (1963) coined the phrase "organised disclusion" as it describes the concept both in maximum intercuspation and lateral and protrusive excursion. Functional occlusion has two basic concepts according to Mohl & Davidson (1988), balanced and mutual protection. Williamson (1976) divides the balanced occlusion into two, bilateral and unilateral, others would create more subdivisions. Tipton and Rinchuse (1991) noted five, differentiating between canine guidance, group function and a mixture of both. A brief description of the main categories follows :-

BALANCED OCCLUSION - Most easily described as your classic denture set up where the teeth glide through functions, and all teeth make some contact. The anatomical factors as well as the tooth morphologic factors have to be in total balance. If there is any immediate Bennet side shift, cusp height has to be reduced nearly to flatness in order to keep from having interferences. Balanced occlusion can be either bilateral or unilateral, the latter philosophy states that when the mandible moves into right working all of the teeth on the working side distribute the load equally, while on the idling or balancing side the teeth are to have no contact. The goal in short is to have simultaneous and equal contacts maintained among opposing tooth surfaces throughout the entire arch and throughout the entire excursion. Stuart & Stallard (1960) summed it up as follows : "To many students of occlusion, it seemed logical to assume the least violent arrangement of oral parts would come from an articulation of cusps in which there would be both bilateral and protrusive balanced occlusion. They held that this classic and revered collective tooth arrangements in which all the teeth were together in nearly every biting situation, would afford a stability because the muscles would strain neither the teeth nor the joints and could not overburden teeth singly." Williams (1971) found that the concept of bilateral balanced occlusion prevailed with most leaders in the field of restorative dentistry until about 1950. It was discarded due to a number of shortcomings he describes as follows; "flexure of the mandible on the balancing side, as the condyle leaves its centric position and slides down the eminence, it is no longer braced by the temporomandibular ligament. The force of the muscle may then cause a slight flexure of the bone which results in an occlusion that is very difficult to keep in balance. Periodontal sequalae and bruxism are the consequence." His summation strongly recommends that bilateral balanced occlusion should be reserved for complete denture prosthetics.

The requirements of bilateral balanced occlusion according to Williams (1971) are as follows :-

1. **Centric Position:** All teeth contact evenly when closed into centric relation. The anterior teeth contact lightly.
2. **Working Side:** The maxillary buccal cusp inclines are in even contact with the mandibular buccal cusp inclines.
3. **Balancing Side:** The teeth opposite the working side shall have a balancing contact between the lingual cusps of the maxillary teeth and the buccal cusps of the mandibular teeth.
4. **Protrusive:** Incisal edges of the maxillary six anteriors are in contact with the incisal edges of the mandibular eight most anterior teeth. There should be a balancing contact between the maxillary and mandibular last molars.

UNILATERAL BALANCED OCCLUSION, OR GROUP FUNCTION This philosophy was introduced in the 1950s by Pankey, Mann and Schuyler, its original goals were advocated as the following, Schuyler (1953):-

i) a static coordinated occlusal contact of the maximum number of teeth when the mandible is in centric relation.

ii) an anterior guidance that is in harmony with function in lateral eccentric positions on the working side.

iii) disclusions by the anterior guidance of all posterior teeth in protrusion.

iv) disclusion of all non-working side inclines in lateral excursions.

v) group function of the working side inclines in lateral excursions.

In essence as the name implies the balancing side contacts had been eliminated from the bilateral balanced philosophy. Williams (1971) summed up the requirements of unilateral balanced occlusion as follows:-

1. **Centric Position:** All teeth contact evenly when closed into centric relation. The anterior teeth contact very lightly. The concept of a long centric has been introduced which is a freedom of the mandible to move in one plane of space from its most retruded position to a point approximately 0.2, to 0.5mm. anterior. The anterior point is delimited by a simple movement of the mandible from rest position to intercuspal position.
2. **Working Side:** The maxillary buccal cusp inclines are in even contact with the mandibular buccal cusp inclines.
3. **Balancing Side:** There shall be no tooth contacts on the side opposite the working side.
4. **Protrusive:** The maxillary six anteriors shall contact the mandibular eight most anterior teeth in an edge to edge relationship. There shall be no contacts of any teeth posterior to the above mentioned ones.

The arguments over these concepts were greatly influenced by dental anthropological studies. Begg, in 1954, wrote: "High unworn cusps are wrongly considered to have evolved to maintain stability of occlusion throughout life, whereas the only advantage of high cusps is that they help to guide the teeth into their occlusal relationships at the time the teeth are erupting and then to hold them only for a short time after eruption." D'Amico (1958) on the other hand was of the opinion.

A. flattened edge-to-edge occlusions seen in aboriginal dentitions were due to excessive attrition and abnormal,

B. a lateral ruminating type of mandibular function in humans is not typical,

C. steeply cusped teeth are entirely appropriate, and

D. the maxillary incisors and canines are meant to exhibit overbite so as to disclude posterior teeth during eccentric positions of the mandible.

Mutual Protection - essentially in centric relation occlusion the posterior teeth take the brunt of the load with very light contact on the anterior teeth; whereas in eccentric functions the anterior teeth protect the posterior teeth from any contact.

The requirements of a mutually protective occlusion are:-

1. **Centric Position :** All the teeth contact evenly when the jaws are closed in centric relation, also called the terminal hinge position. The anterior teeth miss contact by a very small amount. Two thicknesses of 0.0005 mm mylar paper should meet some resistance when pulled from between the incisors at centric relation occlusion.
2. **Working Side:** The maxillary canine should contact the mandibular canine. No posterior teeth shall contact at any point once the jaw leaves the immediate centric position. The objective is for the posterior teeth to disclude by 0.5 to 1.0mm.
3. **Balancing Side:** There shall be no tooth contact on the balancing side.

4. **Protrusive:** There shall be no posterior tooth contact when the maxillary six anterior teeth contact the eight most anterior mandibular teeth in an edge to edge position.

Within this scheme there are two intercuspal concepts:-

A. tooth to tooth or cusp fossa relationship which requires the molars to be in an end to end relationship resulting in a varying amount of anterior overjet. To the orthodontist this appears to be slightly Class II, div. 1; (difficult to achieve in classical orthodontics and still maintain anterior guidance due to the fully corrected Class I molar position). The restorative dentist would have only the canine contacting in disclusion due to the resulting overjet, but it enables him to place each mandibular buccal cusp and each maxillary lingual cusp in an opposing fossa.

B. tooth to two tooth or cusp-embrasure which is said to be the ideally occurring intercuspal position equating of course to the Angle Class I. The term cusp-embrasure is slightly misleading since it suggests each mandibular buccal cusp and maxillary lingual cusp of the premolars will occlude in an opposing embrasure. In reality, a cusp-embrasure relationship ideally places the mandibular premolar buccal cusps in opposing embrasures but the maxillary premolar lingual cusps are in the distal fossae of the mandibular premolars. Andrews (1972) continues to point out the mandibular first and second molars have the mesiobuccal cusps embrasures and the distobuccal cusps in opposing fossae. The maxillary first and second molars have the mesiolingual cusp in fossae and the distolingual cusps in embrasures.

There is a selective pattern of disclusion of non working tooth surfaces during similar mandibular excursions. The pathway the cusp travels as it leaves the fossa will be determined by the condylar guidance. Most natural teeth have grooves running in the correct direction to correspond with the movements of the mandible, provided the tooth is in the correct position. By serving to disclude the nonworking side teeth during lateral excursions and the posterior teeth during protrusive incisal contact, the working teeth or inclines "protect" the non working teeth or inclines. As shown in cuspid protection or group function. Clinically the distinction between canine protection and group function is difficult to make. The differences in rationale are however clear -the modern gnathologic concept of canine protection is based on the assumption that tooth blades and cusps are arranged for vertical chewing, and that cusp-fossa-groove position and form must be strictly intergrated with condylar and mandibular movements so that minimal tooth contacts occur during function. The canines help to prevent the lateral enmeshment of working side posterior teeth, which is considered superfluous and potentially damaging, it is otherwise known as canine disclusion.

McNamara (1977) states that a biologically optimal occlusion ensures a stable neuromuscular pattern of the masticatory system that is self perpetuating. Minimal stress occlusion permits the entire range of the stomatognathic system to function harmoniously, with no excessive demands placed on the joints, ligaments, neuromuscular system, or teeth.

Moyers (1973) and McNamara (1978) believe that all occlusal correction should be aimed at achieving a repeatable median occlusal position by stabilizing the intercuspal tooth position in harmony with the joint relationship. The median occlusal position contacts cannot be captured on mounted casts, as they approximate functional tooth contacts, but are important during occlusal adjustment procedures (Klineberg 1980). Roth (1981) claims that for years the emphasis in describing centric relation of the mandible has been the rearmost position. This, he says has been unfortunate because the emphasis should have been placed upon capturing the uppermost or superiormost position attainable as described by Dawson (1974). In 1967 Mathews stated that a common saying within the dental profession was "centric relation was defined by the prosthodontists, mechanised by their articulators, discussed at great lengths by the periodontists, redefined in oral rehabilitation, and ignored by the orthodontists." This has been due in great part to two reasons:-

i) the controversy that surrounds the definition and the recording of the retruded position,

ii) as Moss (1975) shows "in short time periods the dynamically fluctuant state of the neuromuscular apparatus makes it reasonably certain that intra-individual variation in condylar positions can exist over relatively long periods of time, the morphology of all functional surfaces of the temporomandibular joint is capable of significant adaptive alterations." He therefore disputes the concept of an immutable condylar position, defined as the "retruded position" especially in the growing individual. Mongini (1977) is also in agreement with this view

Dawson (1974) believes that five criteria should be fulfilled if an occlusion is to function with optimal stability and maintainability:

i) Stable stops on all teeth when the condyles are in their most superior, posterior position.

ii) An anterior guidance that is in harmony with the border movements of the envelope of function.

iii) Disclusion of all the posterior teeth on the balancing side (the side of the orbiting condyle).

iv) Disclusion of all the posterior teeth in protrusive movements.

v) Non-interference of all the posterior teeth on the working side, with either the lateral anterior guidance, or the border movements of the condyles.

This view is supported by Roth (1976), Behrend (1969) and Barnett (1978). McHorris in 1979 stated "nothing pleases occlusion-conscious dentists more than to see orthodontically treated teeth with good centric closures, and effortless disclusions, provided by proper horizontal and vertical overlaps of aesthetically pleasing anterior teeth." It is not surprising that with two of his papers placing special emphasis on the functional and parafunctional role of anterior teeth McHorris believes that the anterior teeth are the key to preserving good occlusions. Proffit & Ackerman (1970) put things into perspective - "In certain Melanesian Islanders, the usual condition is what we would call a skeletal Class III malocclusion, with good dental alignment. Thus, incisal guidance, cuspal protection and the like, which are useful therapeutic concepts, are not biologic necessities." Zimmer, Jager and Kubein-Meesenburg (1991) write in their paper that mediotrusive and protrusive tracings are generally flatter in Class III individuals than either Class I, or Class II groups.

From this one ought to begin to realise that there is no single rule or primary period of importance in correlating and applying present day concepts of occlusion to orthodontic therapy. However it is suggested the most dangerous position is not the person who holds an occlusal scheme which may be in disrepute, but rather the man who has no occlusal scheme and simply lets the teeth "fall where they may." Beyron (1969) believes there is no normative form, and occlusal disharmony cannot be described in terms of deviation from an idealised type of occlusion. Most authors agree, however, that for the purpose of treatment it is necessary to recognise certain characteristics of an optimum occlusion, so that the orthodontist has a basis or goal upon which to treat. Williamson (1976) categorically states there is a need to know where we are going before we begin. It is for this reason that a functional goal, and testing procedures for it are needed concomitantly with the static goal. Proffit (1986) quotes Lewis Carrol to make the same point by saying if you don't know where you're going it hardly matters which road you take.

CHAPTER 4: MALOCCLUSION, NORMAL AND IDEAL

The term normal occlusion has been defined by Strang (1950) as follows, "Normal occlusion of the teeth is the normal relationship of the so-called occlusal inclined planes of the teeth when the jaws are closed, accompanied by the correct proximal contacts and axial positioning of all the teeth and the normal growth, development, location and correlation of the various associated tissues and parts."

Duval in 1802 is one of the first authors said to have recognised that there was an ideal arrangement of the teeth and the need for its preservation. According to Hahn (1944) he wrote that "it is not sufficient that the teeth are properly arranged at the side of each other; those of the upper jaw have a special connection with those of the lower, the least deviation from which diminishes the beauty of the appearance, frequently renders their function Labourious, and may often tend to their mutual destruction."

Angle (1907) went one further a century later in saying, "For were the teeth created Solely for occlusion? Study their shapes, study their forms and proportions, examine them microscopically, study their positions and periods of eruption, and the very structure and arrangement of that wonderful membrane that holds them in position, and, too that peculiar structure, the alveolar process that comes at their bidding and vanishes with their going - all, all point to occlusion and the one grand object of its function."

Angle (1907) like Strang and many others approached the subject of occlusion from the idealistic standpoint. Angle felt that the size, forms, interdigitating surfaces and positions of the teeth in the arches are such as to give one another, singly and collectively the greatest possible support in all directions. He believed that nature intended all parts of the human denture to be in harmony, not only with each other, but also with the rest of the associated parts of the face and mouth. Of the human denture and its associated structures he thought that the mechanical principles, utilised by nature in its construction were marvelously adapted to the demands of the situation.

I have a greater empathy with the comment offered by Wylie (1947), "orthodontics requires sober reflection upon the limitations imposed upon even the best among us, and at the same time demands that we do the best we can within those limitations. As architects of the human face we should give up the vain search for what nature intended and face the fact that nature has no intentions at all. Let us instead study more thoroughly and define more clearly what we intend to do with the facial pattern." Stallard (1926) is in agreement with this but tries to bring the concept of normality to a respectable state. He explains how teeth deeply locked by malocclusion are freed by delicate forces. Interdigitation of teeth aid in keeping them properly located but it is only a minor part of retention. He points out that even after a long period of mechanical retention there are many instances of relapse. This he finds is not surprising since if the external and internal factors of life fail to produce normal occlusion, then, that made by interference would not last for long. Williams (1921) disagreed and put forward the concept that improved techniques would allow accurate cusp and axial relationships. He continues by locating the teeth in true skeletal relationships and places the occlusal surfaces in spherical occlusion with a typical curve of Spee in exact harmony with the condylar movements, this he said means failure would become a thing of the past. Almost the right idea and certainly far easier said than done.

Greenstein (1961) states "settling in is the movement of teeth after appliances are removed, in response to the various forces to which they are subjected, particularly the anterior component of force, the pressure of the lips, tongue and cheeks, and the influence of the cusps of teeth in the opposing jaws." Strang (1950) preferred the term readjustment, stating "inert things settle, living structures make readjustment." It is the "normal occlusion" which is achieved on the completion of orthodontics that should be evaluated from the standpoint of a passive occlusal relation of the arches. Halderson, Johns and Moyers (1953) state, "Relapse of any case is nothing more than a failure to place the teeth into a stable position of equilibrium among the forces acting on the denture. Until a great deal more work is done, we shall continue to see a few perfectly treated cases fail to retain well."

Ottolengui in Stallard's paper of 1926 comments on normal occlusion he tells us it implies an occlusion is in agreement with a norm. He qualifies this by pointing out no two things are identical, a norm is, to a limited extent, subject to variation, which would still be within the range of that which is normal. So essentially it is suggested a normal occlusion in human beings predicates a standard of occlusion, variable within definite limits. Proffit (1986) calls this his envelope of discrepancy, a variation which still allows normal function. Normal occlusion then becomes a type of occlusion that, within certain variations is theoretically common or feasible with all races of men. Ottolengui maintains that functional occlusion is quite different, it is a condition limited to an individual, and is never duplicated in any other individual. It is such contact of the teeth of both jaws as will provide the highest efficiency. He believes given a particular set of teeth, there is but one arrangement that may be made of them that will constitute functional occlusion. Fischer (1952) points out that it is possible to arrange the teeth for the same individual in a variety of arch forms, axial inclinations and positional relationships of the arches to the surrounding structures. Any changes in the anatomic relationship that the operator produces in the treatment of a given individual must, therefore, be considered the result of an arbitrary decision.

Stallard (1926) is convinced that a normal occlusion exists, in the mind if nowhere else. But as he points out men's minds differ. The theory of a normal occlusion is required as it serves as a pattern or arrangement of the teeth towards which the orthodontist must aim when treating maloccusions. The problem being according to a number of authors Strang (1950), Stallard (1926) and Angle (1907) that a normal occlusion occurs so infrequently the majority of dentists have seldom seen it; and the dentist be he orthodontist or prosthodontist, has difficulty in visualising the pattern he is asked to imitate. As Angle stated in his 1907 paper "malocclusion has become so common that it is now almost the rule." So with regard to the normal occlusion Strang (1950) writes that it must be visualised in each and every case that comes under one's care. It cannot be written of with complete satisfaction, he uses a quotation of I.E.Gould who apparently said regarding the line of occlusion "while we all have the ability to think of things, other than material, in clear terms, we cannot manifest such thoughts through tangible illustrations." He continues this justification with the following analogy, "One cannot accurately or with justice, visualise God. Painters have placed the image of the Divine Being on canvas, but the picture represents only their personal conception of the Supreme One. It lacks the reverence and love that is an inherent part of each individualistic image of the Master. In like manner, one cannot picture the plan of occlusion in written sentences. Each must really live this concept in his daily life. In this way it truly becomes a most practical law and guide in addition to being a most beautiful and wonderful law of nature."

Despite this many descriptions of the ideal occlusion have been proffered, one from the Nomenclature Committee of the American Association of Orthodontics (1950), stated of occlusion "It is basically a myth; it is a figment of the imagination as the ideal occlusion is not easy to learn as it is not static. It is changing all the time as the individual grows and develops." Friel (1954) however maintains that the ideal occlusion does occur in nature but in decreasing numbers as the final stages of development are reached. To his mind it was the most important form of occlusion to be known.

The choice of a standard is greatly enhanced by the concept of malocclusion. Due to natural variation, biologic traits may be arranged in a series of increasing or decreasing normality. The range of traits or characteristics however is so great that the gradations from one extreme to the other form a continuum. Any point that is established as dividing the normal from the abnormal must necessarily be an arbitrary one. The clinician is interested in the measurement of malocclusion and requires a standard of comparison for the evaluation of both "normal" and "abnormal." In 1932 the White House Conference on Child Health and Protection put forward this solution. "A sound principle would seem to be to try to establish empirically the point with respect to each trait under consideration at which some definite handicap or dysfunction begins to be associated with extreme variation."

As Fischer (1952) points out an extreme variation or deviation that can be identified with a definite handicap or dysfunction does not require a biometric norm for its detection. Whilst natural variation is a valid yardstick for decisions not to treat certain conditions it should not be allowed to interfere with the standard of treatment to which we aspire. We will find an imbalance between the size of the teeth and the size of the arches, an imbalance between the size of the mandibular and maxillary arches, an imbalance between these dental arches and their surrounding structures.

Ballard (1944) makes the point that both orthodontists and general practitioners believe that the dental apparatus of man is a potentially a perfect machine, harmonious in all its parts, needing only a skilful rearrangement by the orthodontist to render it functionally and aesthetically perfect. He continues to point out that any patient who is taken to the successful completion of treatment on a cursory examination validates this view, however when the result is analysed in minute detail it is invariably manifestly deficient.

He uses as an analogy the state of balance that exists between a set of gears that are run at high speeds and the expectation that the dental apparatus through the articulating surfaces should also achieve this balance and harmony. Not only should it achieve this balance but also maintain it after the removal of the retaining appliances. That this is not often the case and relapse rears its ugly head suggested to Ballard that some cases must violate the first requisite, that of balance amongst the component parts.

Ballard specifically looked at asymmetry in tooth size and found that 90% of a 500 sample had an imbalance of tooth size between right and left sides of the dental arch of over 0.25 mm. Stifter (1958) came back to the same problem of predicting the harmony of tooth size to arch size, maxillary arch to mandibular arch size and arch size to its surrounding structures. He tested five prescribed model analyses:-

1. Pont's index purports to give an indication of the degree of narrowness of the dental arches in a case of malocclusion, and also the amount of lateral expansion required in order that the arch be of sufficient size to accommodate the teeth in perfect alignment. From a measurement of the four maxillary incisors.

2. Howe developed his analysis on the premise that in normal dentitions, the width of the maxilla in the first premolar must be at least 43% of its tooth material.

3. Rees' method of assessment looked at the relationship that existed between the maxillary apical base, mandibular apical base, maxillary tooth material, and mandibular tooth material.

4. Neff's Anterior Coefficient was obtained by measuring the sum of the mesiodistal diameters of the six upper anteriors and dividing into that the sum of the mesiodistal diameters of the lower anteriors.

5. Bolton's analysis determines a ratio of mandibular tooth material to maxillary tooth material. By using this ratio and comparing it to his standard, the arch that is deficient is determined. The amount of the discrepancy is determined by referring to a table which predicts the amount of tooth material that the deficient arch should have.

Stifter found that each of the analyses had a significant correlation to "ideal" and "normal" occlusions but refrains from endorsing them as a complete and valid tool for diagnosis.

Model analyses are/were done for two major reasons, the assessment of the possibilities of tooth movement and the prognosis of denture stability after treatment. Kesling (1956) with regard to his diagnostic set up stated that since neither apical base nor tooth size can be altered materially, intelligent rearrangement of the plaster teeth on the model can replace the confusion of speculation with concrete objective manipulation. He cautions that under no circumstances should arch length be gained by increasing the third dimension, or arch width, greater than the apical base can accommodate.

Proffit (1986) tells us that diagnosis should be comprehensive, in orthodontics it is an inaccurate diagnosis to characterise the dental occlusion while overlooking a jaw discrepancy, developmental syndrome, periodontal problem or systemic disease. The natural bias of any specialist is to characterise problems in terms of his own special interest. To avoid this he recommends the problem oriented approach.

Fischer (1952) writes the most important requirement for a standard to be used in orthodontic diagnosis and treatment is that it be applicable to the individual. As such it must contain three conceptual ingredients of the normal - the "anatomic," the "functional" and the "aesthetic" which form the basis of orthodontic objectives. Proffitt (1986) writes of similar objectives - ideal occlusion, functionally and statically; ideal facial aesthetics; and ideal stability of result. They both realise it is often impossible to maximise all three goals and so the concepts must be compromised to various degrees in the treatment of different individuals. Obvious compromises have been made in the past, attempts to achieve an ideal dental occlusion have often compromised facial aesthetics - the "dished in" face. Instability after treatment is often found in trying to procure optimal facial aesthetics. Two points come from this, Fischer (1952) highlights the fact any standard that is formulated upon the basis of a statistical norm casts all individuals into a preconceived "anatomic", "functional" or "aesthetic" mould and ignores the individuality of the dentofacial complex. Proffitt (1986) suggests emphasizing one of the goals at the expense of the others. The best example of this was Angle who chose to solve the problem by focusing on the occlusion and declaring that facial aesthetics and stability would take care of themselves. Proffitt is of the opinion if all of the three major goals of orthodontic treatment cannot be reached, those of greatest importance to that patient should be favoured.

To do this it must be remembered that the "normal" of the anatomic relationships of the dentofacial complex is not clearly definable and is practically unknown for one particular individual. The orthodontist should change relationships between the teeth that are considered detrimental to the health and longevity of the denture. Finally the goal should be formulated with regard to the possibilities and limitations of orthodontic operations and the changes that can be produced by them in the anatomic parts and their relationships.

Stallard (1926) closes his paper with remarks about his major concern of aetiology of a malocclusion causing the return after treatment, "the more I study the more hopeless my faith in empiric treatment." Proffitt on the other hand writes "whatever the malocclusion, it is nearly always stable after growth has been completed. If an orthodontic problem is corrected in adult life, which can be difficult because so much treatment depends on growth, a surprising amount of change is also stable. The aetiologic agents, in other words, are usually no longer present when growth is completed. Malocclusion, after all is a developmental problem."

Jankelson (1960) tells us before proceeding with the clinical adjustment of the occlusion that the dentists should have a clear understanding of what has happened to disrupt it and what is required to restore it to a favourable functional state. Brabant (1981) demonstrated there is no direct correlation between occlusal "form" and occlusal "function" which supports the multifactorial aetiology of occlusal dysfunction. To the orthodontist malocclusion is seen as a dentofacial deformity and malalignment of teeth. To the gnathologist however when he uses the term "functional malocclusion" or "deflective malocclusion" he is really referring to malarticulation. That is the teeth fit into occlusion and an anatomic alignment may have been achieved, but there is some disharmony existing in either closure or during mandibular excursions in which the teeth deflect mandibular movement. As Roth (1981) writes this in essence means to the gnathologist that -

1. it is possible to establish a good anatomical occlusion and still have malarticulation,
2. it is possible to have some degree of anatomical malocclusion and still have good articulation.

CHAPTER 5: ORTHODONTICS, OCCLUSION AND TOOTH CONTACTS

Many papers have been written concerning the relationship between functional occlusal interferences in orthodontically treated and untreated subjects. A review of the ones most frequently cited in the current literature will be presented with relevant comments from others.

Cohen (1965) compared occlusal interferences in orthodontically treated and untreated normal occlusions. He sat the patient upright and then asked them to open and close the mouth in rapid succession and evaluated the occlusion according to the sound. (gnathosonics) He then used Kerr wax (otherwise known as Occlusal Indicator) and recorded centric relation and habitual bite. This method was suggested by Jankelson (1960) in his paper -"A Technique For Obtaining Optimum Functional Relationship For The Natural Dentition" Prematurities were then charted according to their location as to tooth, cusp and cusp surface. A second reading was done at a later stage and whenever there was a discrepancy between the two, further investigation was instigated. All malocclusions were included in the sample of forty subjects; 13, being Class I; 25, Class II div. 1; 2, Class II div. 2 and 1, Class III. Only seven were treated non extraction. The ages of the treated and untreated groups were comparable, 15.9 and 15.7 years of age respectively.The time out of treatment varied from 2 months to 6.5 years.

Cohen found that 90% of the treated and 91.7% of the untreated group had prematurities in centric relation. This increased to 91.7 (treated) and 94.4% (untreated) prematurities in the habitual bite. The patients in both groups had similar prematurities in either centric relation, habitual bite, or both. With regard to individual mandibular teeth, prematurities were recorded on the following teeth in order of frequency 1st molar, 2nd molar, 2nd premolar and canine.

A glide or shift of the mandible following the initial contact of the teeth was seen in 75% of the treated and 80% of the untreated patients. A tooth positioner had been worn by 50% of the treated patients - they still demonstrated prematurities. Instability in the treated patients was stated not to have been a problem. The patients were said to have been unaware of the presence of premature contacts or glides.

He concluded that although patients had received treatment that satisfied generally accepted objectives they demonstrated prematurities in function. There was a great similarity in frequency and location of these prematurities to persons with "normal" occlusions. It made Cohen aware of the deficiencies in the normal assessment of orthodontic finishing. However he pointed out the importance, or the effect of the occlusal prematurities on the dentition was still a matter of conjecture and open to further research.

Rinchuse and Sassouni (1982) looked at 49 post orthodontic subjects 24 of whom had extractions as part of treatment and 27 non-orthodontic "ideal" occlusions. Records of the tooth contacts were achieved using a bite registration material. All functional; records were initiated from centric occlusion (maximal intercuspation). Contacts were also checked in protrusive and right and left lateral excursions. The occlusions were separated into the following categories:-

		Ortho	Non-ortho
1.	canine protected occlusion	1.4%	5.2%
2.	group function occlusion	1.4%	0.0%
3.	bilateral balanced occlusion	46.0%	22.3%
4.	balanced occlusion one side	15.7%	7.8%

They found that the number of nonworking (balancing contacts) were 96 for the orthodontic extraction cases, 104 for the extraction cases and 90 for the non orthodontically treated cases. Although there was a slight difference between the mean number of balancing contacts among the three experimental groups, it was not statistically significant. For individual teeth the 2nd molars had more contacts, Cohen (1965) found it was the 1st molar which exhibited most prematurities. Roth (1981) suggests it is more likely to be the 2nd molar, this will be accentuated when the 2nd molar is not banded during the course of treatment as was the case with Rinchuse and Sassouni (1982). Tipton and Rinchuse (1991) suggest that the typical position of the mandibular 2nd molars is in the ascending ramus of the mandible, which would necessarily elevate them (natural curve of Spee). This could account for the greater occurrence of non-working contacts for these teeth. Again the goals by which the orthodontic treatment was evaluated were static, no attempt was made to achieve any specific functional occlusion. As a result (97% of the treated and 85% of the untreated subjects had non-working - balancing side contacts. The conclusion reached from this was that the eccentric occlusal contacts of orthodontically treated and comparable untreated subjects were similar. (but not "ideal")

Rinchuse and Sassouni also published in the Angle Orthodontist the following year 1983, using the same material, the emphasis being on functional occlusion as opposed to tooth contacts. One comment of interest was "since there is often a direct relationship between cuspid wear and balancing side contacts, it is possible that the ideal static is also related to a more even distribution of tooth contacts and attrition than Class II malocclusions, where cusps make minimal contact during functional excursions." It is not surprising that their conclusion was the same as the 1982 paper, in that the lateral and protrusive occlusions of post orthodontic subjects and comparable non orthodontic subjects are equivalent.

Gazit and Lieberman (1973a) carried out a comparative study of orthodontically treated (extraction and non extraction) and non-orthodontic (good and poor occlusions) "normal" subjects. The total surface contact of the teeth being the measured in intercuspal ie. centric relation. Compound bites were obtained and transilluminated, a light meter was used to measure the amount of light passing through the wafer to give a direct correlation to the tooth surface contact. They found that the untreated poor occlusion gave a statistically lower reading than the others. The good occlusions and orthodontically treated groups demonstrated similar results with most non-working (balancing) contacts on the 2nd molar.

In a second paper that year, Gazit and Lieberman (1973b) on occlusal considerations in orthodontics highlighted poor tooth contact in intercuspal relation, with lack of incisal or canine guidance in working excursions of the mandible. The authors strongly recommended that the orthodontist ought to refer to the functional phase of occlusion on an equal basis and in close harmony with the anatomical aspects. Treatment advocated by the authors included selective tooth grinding.

Gazit and Lieberman (1985) point out that orthodontic treatment objectives are, broadly stated, improved function and aesthetics yet an informative and detailed examination and evaluation of interarch occlusal contacts has not been a routine orthodontic practice. They opted to measure the occlusal contacts using a photocclusion technique as opposed to the more commonly used indicator wax or coloured articulation paper. The principle of photocclusion is based on memorised birefrigence, a photoplastic wafer is permanently deformed when it is bitten. The wafer is placed on an optical instrument which allows polarised light to pass through the wafer. Where it has been deformed by occlusal pressure isochromatic coloured stress patterns are seen. Twelve post orthodontic patients were studied, four having had four bicuspids extracted. The patients were all originally diagnosed as having a Class II div. 1 malocclusion before treatment. Occlusal recordings were made in intercuspal at bands off and one year later. Two consecutive bite recordings showing "excellent similarity" were required. They divided the contacts into light, medium and heavy, most contacts being in the premolar and molar region, with heavy contacts being confined to the molars.They found that the number of contacts increased over a year for all twelve patients, and thought this confirmed the clinical impression that" nature" brings the teeth more precisely together than orthodontic appliances. "Nature most probably being the process of continual eruption and functional adaptation. They found it odd that the number of occlusal contacts varied initially between 5 and 18,and after a year, 9 and 25 (the extraction groups being similar to the non extraction group) when all patients demonstrated an almost ideal buccolingual and mesiodistal relationship when viewed on study models.

The average number of contacts was 17.4 after a year which was comparable to that found by McNamara and Henry (1974) of 19.7 in teenage males, and 17.1 (orthodontically treated) and 18.4 (non orthodontic "normal") found by Riise (1982). Riise also reported the number of tooth contacts varied dependant on the biting force used, the greater the force the greater the number of contacts. Berry and Singh (1984) found that the number of tooth contacts could vary by as much as 15% dependant on the time of day - morning or after noon - they were recorded. The amount being greater than the total increase in tooth contact some researchers such as Durbin and Sadowsky (1986) found. They were to suggest the gain in tooth contact (14%) was a clinically significant improvement in the occlusion over the three months.

Durbin and Sadowsky (1986) examined 38 patients immediately after treatment and again 3 months later, all patients in the study were considered to have an "optimum occlusion." The tooth contacts were looked at in the intercuspal position and registered using a polyether rubber impression material. A second registration was taken to assess reproducibility. Tooth contacts were also recorded intraorally using articulating ribbon to verify the perforations in the impression material. The 38 patients were divided into two groups one of which wore conventional retainers (23 in number) and the second which used gnathological rubber tooth positioners (15 in number), both groups included extraction (22) and non extraction (16) patients. The authors set themselves the task of answering three questions:-

1. What is the number and location of occlusal contacts in maximal intercuspation at the end of orthodontic treatment?
2. What changes occur to occlusal contacts over a three month period ?
3. What is the difference between conventional retainers and positioners over the three month period ?

They found that the number of tooth contacts increased 14% over the 3 month period, from 10.1 to 11.5 contacts, or 13.0 to 13.7 teeth in contact. The positioner group demonstrated a slightly greater increase than those wearing conventional retainers. Gazit and Lieberman (1985) found an increase of 64%, Dawson and Arcan (1981) found a mean increase of 56%. There was no significant difference between the extraction and non extraction groups. They noted that "post treatment settling" can be beneficial and desirable, such as improved interdigitation of teeth: others may be considered undesirable and constitute prematurities or relapse. The study was felt to support clinical observations of practitioners that the interdigitation of teeth generally improves after orthodontic appliances are removed and teeth are allowed to "settle." They found that those patients with the least tooth contact at the end of treatment had the greatest gain, this was not the case for Gazit and Lieberman (1985).

Razdolsky, Sadowsky and Begole (1988) examined occlusal contacts in forty patients at the end of active orthodontic treatment and again 21 months later. The subjects were stated to have been treated to an "optimum occlusion" and included both extraction (21 in number) and non extraction (19 in number) cases. It was essentially a follow up to the article of Durbin and Sadowsky (1986), the subjects included various malocclusions - 19, Class I; 14, Class II div. 1; 2, Class II div. 2; and 4, Class III. The occlusal registrations were again done using a polyether rubber impression material, two registrations being taken to ensure reproducibility. They found that there were three variables with regard to changes of contact. They could:-

1. remain the same,
2. move toward the fossa,
3. move away from the fossa.

This is of interest as it had always been assumed that if contacts are left on an incline then they will settle towards the central groove. Razdolsky, Sadowsky and Begole (1988) found that this is not always the case, on average only 1.5, or 10% of contacts moved towards or away from the central fossa. In general the number of tooth contacts increased over the 21 month period from 17.5 to 20.7 contacts. The variation in contacts was a loss of 7 teeth or 19 contacts to a gain of 19 teeth or 59 contacts, 92.5% of the cases had a net increase in the number of tooth contacts. The authors made a strong recommendation that when the appliances are removed the occlusion should be as ideal as possible due to the fact contacts do not always settle as expected. They do however advocate the use of overcorrections in some unspecified instances. One difference between this and other studies is they found an appreciable increase in anterior tooth contact. The authors agree that one of the characteristics of an "ideal occlusion" is having an 0.5mm clearance between incisors in centric occlusion.

Tipton and Rinchuse (1991) looked at the relationship between static occlusion and functional occlusion in a dental school population. They selected 101 students who had no prior orthodontic treatment, 28 teeth and no large restorations or crowns. A variety of occlusions were represented, 52 of the subjects had a "normal static occlusion," 26, Class I malocclusions; 16, Class II malocclusions, and the remaining 7, Class III malocclusions. The study found no statistically significant relationship between static occlusion and functional occlusion. There was however a trend for balanced occlusion to be more often associated with "normal" (ideal) static occlusion.

Functional occlusal contacts were directly and visually determined through use of articulating wax and dental floss. The authors thought it important that one should know if a relationship exists between static occlusion and functional occlusion, and should such a relationship exist, which type of static occlusion was associated with which type of functional occlusion. Predictably enough, the investigation failed to demonstrate a relationship between static occlusion and functional occlusion. There was however a trend for balanced occlusion to be more often associated with a "normal" (ideal) static occlusion. Overall 75% of the 101 subjects demonstrated non-working (balancing) functional contacts. The authors however concluded it is possible that an optimal functional occlusion type exists for each of the various static occlusion types and is compatible and harmonious with patients stomatognathic systems. They divided the functional occlusions into:-

1. Canine protected occlusion (9%)

2. Group function occlusion (9%)
3. Mixed canine protection / group function occlusion (8%)
4. Unilateral balanced occlusion (34%)
5. Bilateral balanced occlusion (40%)

The static occlusions being categorised according to Angle.

Ehrlich and Taicher (1981) looked at 29 individuals chosen from 720 on the basis of possessing the following:-

a) Angle Class I, good alignment and no prior orthodontic treatment;
b) complete dentition (28) teeth;
c) no periodontal disease or temporomandibular joint problems;
d) good oral Hygiene.

Bite registrations were carried out using wax wafers in maximal intercuspation, a second registration was carried out to ensure reproducibility. The wax bites were then viewed in front of a light screen and the occlusal contacts were divided into the following categories:

- i) supercontacts, penetration of the wax;
- ii) contacts, translucent area of wax;
- iii) near contact, thinning of the wax.

The exact position of the contacts was then marked on study models. They found on average the number of occlusal contacts for the patients were 79, the range being from 40 to 110 (80 being described as contacts). With regard to supercontacts (heavy) there was a predominance on the 2nd molars. All patients were described as having a morphologically sound occlusion and the authors found that this did not equate to maximal tooth contacts, as an ideal occlusal contact pattern was not found for any subject in the survey. The tooth which had the most contacts was the first molar hence its importance in chewing. The relevance of supercontacts was not explained, though it was thought to be associated with maximum muscular force on closing. The authors posed the question as to wether occlusal contacts were stable or not throughout life? One would imagine functional adaptation must accompany occlusal and interproximal attrition.

Sullivan *et al.* (1991) compared occlusal contacts in treated orthodontic patients and untreated controls. They tell us there is an undeniable dependence between static and functional contact patterns. They find it unlikely that one can achieve the ideal and highly stylised occlusal patterns published in dental text books.

They looked at four groups, a treatment group of 19 adolescents with either a Class I, or Class II, div. 1 malocclusion, the control group was made up of 18 adolescents of unknown malocclusions. The two other groups were mature persons of also of unknown malocclusions, one, the control of 29 persons having had orthodontic treatment and a treated group of 26 persons.

Occlusal registrations were made in a manner similar to Durbin and Sadowsky (1986) and the number of contacts counted. The contacts were grouped - anterior contacts, posterior contacts, total number, and according to size. The control adolescents had a mean number of 14.95 contacts, the treatment group diminished to a mean of 7.26 contacts. They found this was somewhat less than the 10.1 contacts of Durbin and Sadowsky's debanded group. They postulated that there could be a rapid settling of teeth with the removal of appliances. The mature groups showed 15.27 contacts in the treated group and 19.0 in the control group. In that latter group the tooth contacts varied between 7-36 contacts with few recording over 30 contacts. This is in comparison to Ricketts suggested ideal of 48 occlusal stops in the absence of third molars.

They concluded that close attention to finishing and occlusal adjustment would ensure more tooth contacts. They caution against occlusal adjustment in the settling period and correctly point out that it has yet to be demonstrated that the reduction in the occlusal contacts has a functional significance. They agreed that anterior contacts were limited and more closely approached the "ideal" requirements.

Haydar, Ciger and Saatci (1992) also looked at occlusal contact changes after the active phase of orthodontic treatment. They viewed 30 patients in three groups, untreated control, those treated then retained with Hawley plates, and those treated and then retained with positioners. Again occlusal records were taken with a silicone based impression material similar to Durbin and Sadowsky (1968) at the end of treatment and then three months later. Contacts were transferred to study models and standard photographs taken. They found that their normal occlusion group had a mean of 39.4 contacts originally that increased to 40.5 contacts three months later. The number of contacts had increased on the second molars and diminished on the fist molars. The treated group had mean numbers of 21.2 contacts for the Hawley retainer group increasing to 22.4 after three months and 24.8 for the positioner group increasing to 27.0 contacts.

They found no significant change in the location of contacts over the three month period. Occlusal changes were seen in the control group and it suggests occlusal contacts should be expected to change in all patients particularly those still growing. The use of a positioner over a retainer did not significantly alter the number of tooth contacts.

Authors	Number of Tooth Contacts	
	treated	non-treated
McNamara & Henry 1974	19.7	
Ehrlich & Taicher 1981		79 (range 40-110)
Riise 1982	17.1	18.4
Gazit & Lieberman 1985	17.4	
Durbin & Sadowsky 1986	10.1 increasing to 11.4	
Razdolsky, Sadowsky & Begole 1988	17.5 increasing to 26.7	
Sullivan *et al* 1991	adult: 15.3	19.0
	adolescent: 7.3	15.0
Haydar, Ager & Saatci 1992	21 increasing to 27	39.4 increasing to 40.5

Other authors who have written about occlusal interferences in orthodontically treated and untreated subjects include Thompson (1956), Ahlgren and Posselt (1963), Bruno (1971), Roth (1973), and Wasson (1979) they all comment on cuspal interferences or tooth contacts forcing the mandible to deviate from a physiologic pattern. They term it a neuromuscular avoidance mechanism or pattern. They also point out it cannot be controlled by the patient who is often unaware of it, so it may mislead the dentist or orthodontist who is trying to locate the prematurity in the mouth. For this reason it is advocated that one should mount casts on an adjustable articulator.

Posselt and Ahlgren (1963) commented on functional analysis and the need for selective grinding. They screened 120 (mean age 11) pre-orthodontic malocclusions and found cuspal interferences in 55% of the cases. Another 23 orthodontically treated patients (mean age 14) were viewed showing cuspal interferences in an average of 61% of the cases. They too found no correlation between Angle's classification and functional malocclusion. They were however concerned about the effect of crossbites, there being an increased number of cuspal interferences being associated with them.

Heide and Thorpe (1965) looked at 10 orthodontic cases after treatment and found that in no instance did centric relation and centric occlusion coincide a point Roth (1981) makes quite forcibly. Interestingly enough Andrews (1990) has added the need to treat to centric relation to his six keys and credits Roth for bringing its importance to his attention. McNamara and Henry (1974) point out that tooth contacts varied quite dramatically (decreased) when their subjects moved from centric occlusion to centric relation. Whilst Mathews (1967) was of the opinion prematurities in tooth contact should be expected after extensive orthodontic tooth movement. Aubrey (1978) believes that prematurities are always present to some degree in the finished orthodontic patient and he is certainly well supported by the other authors reviewed.

Reviews of Functional Occlusions

Authors	Cuspal Interference		Prematurity of Contacts		Non-working Contacts	
	control	treated	control	treated	control	treated
Posselt & Ahlgren 1963		55%				
Cohen 1965			91.7%	90%		
Rinchuse & Sassouni 1982					85%	97%
Tipton & Rinchuse 1991					75%	

Woda, Vigneron and Kay (1979) in a review of functional occlusion concluded that pure canine protection or pure group function rarely exists and balancing contacts seem to be the general rule in the populations of contemporary civilisations. This supports the findings of the following who all found a predominance of balancing contacts Tipton and Rinchuse (1991) 75%, de Laat and Von Steenberghe (1985) 61%, Sadowsky and Begole (1980) 89%, Rinchuse and Sassouni (1983) 85%, and Ingervall (1972) 85%. They also point out in their article that therapeutic acts which modify occlusal anatomy are supported by various concepts which all refer to an "ideal" occlusion. This "ideal" occlusion has been described in several ways but rarely on an experimental basis. The principle articles on occlusal contacts being centred on occlusal relationships of dentitions subjected to neither iatrogenic nor pathologic factors. It is my intention to describe these ideal tooth contacts through experimentation using acrylic "normal" teeth in simulated orthodontic treatments, including both extraction and various non-extraction treatments.

CHAPTER 6: GNATHOLOGY AND THE ELEMENTS OF ARTICULATION

Gnathology was first coined by B. McCollum and H. Stallard according to Lucia (1979) to describe the study and treatment of the entire dentition as a functioning unit. The emphasis being placed on the fact that the teeth actually function as a unit along with the temporomandibular joints, the jaws, and the components of the neuromuscular system.

Primarily each tooth position and its importance to the function of the entire system. Stallard and Atkinson were two orthodontists actively involved in the early years of the Gnathological Society. Gnathology is an attempt to create an occlusion whereby the teeth articulate in such a manner that they are in perfect correlation with the possible border excursions of the mandible. The border positions of the mandible are represented by the limit of mandibular movement in all directions as outlined by Posselt in his work on the "envelope" of mandibular motion. In this way the occlusion requires the least amount of neuromuscular adaptation by the patient. The principle is used routinely in:-

Occlusal equilibration,

Occlusal morphology in restorative and prosthetic dentistry,

Basic rationale for some in treating TMJ dysfunction syndrome,

In its simplest terms it is an attempt to allow the TMJ to function without being subservient to teeth.

Stockli (1981) says of the gnathologic concept of occlusion "the system is so perfect that Nature is embarrassed in an attempt to comply with all its requirements. The orthodontist, confronted is also troubled by his attempt to create an end result that, from a gnathological standpoint, is and must remain impeccable. "It is thought by many that the greater the differential that exists between the occlusion and the dictates of the TMJ the more necessary it becomes for the neuromuscular mechanism to adapt. If the adaptive facility is exceeded stress is introduced into the system. If the stress is greater than the patients tolerance then disease symptoms will ultimately show, this may be in the form of clicking of the TMJ, muscle spasm, limitation of movement, excessive wear on the teeth, mobility of the teeth etc.

Victor O. Lucia (1969) gives the characteristics of a gnathologic articulation as follows:-

The teeth interdigitate when the mandible is in centric relation, centric occlusion should be coincident with centric relation. The gnathologic occlusion demands control of all the chewing surfaces at the same time.

The elements of articulation (cusps, blades, ridges, fossae and grooves) should be present without clashing. They are said to keep lateral stresses to a minimum and transmit the forces of articulation to the long axes of the teeth.

Roth (1981) states that he has found the following to be the case in the patients he has treated:-

A. Natural tooth structure is not necessarily correlated to condylar guidance or border movements of the mandible to any degree that begins to approximate perfection, although in some instances there may be a high degree of correlation.

B. The ability of the operator to satisfy gnathological goals through orthodontic therapy is independent of whether or not teeth were extracted.

C. The greater the skeletal imbalance or configuration from "normal" the more difficult it becomes to achieve ideal gnathological goals.

D. Tooth size discrepancies and morphological differences will greatly affect the operator's ability to achieve an ideal result.

E. It quite often requires the use of a positioner.

F. It aids retention greatly if occlusal adjustment is such that the occlusion conforms to gnathological goals.

G. Correct axial inclinations of each tooth is of prime importance in establishing the best possible functional result.

He concludes that in the future some of the more empirically chosen treatment goals in orthodontics will be discarded in favour of goals that will offer a more favourable functioning occlusion.

As Ricketts (1969) writes (a shade reminiscent of Angle) each tooth seems to possess its own design; it occupies a precise place and serves its function in relation to its neighbour and to its antagonist. When it comes to placing a tooth in its correct position for a normal occlusion the literature Stallard (1926), Ottolengui (1930), Stallard &

Stuart (1964), Ricketts (1969) and Roth (1981) tell us most dentists have memorised the incline plane relationships of teeth as a student, the details however of an ideal relationship in terms of occlusal or centric stops and of axial contact relations are often missed or too often assumed.

Lucia states that it does not matter if the articulation is a fully balanced one, or a cusp to fossa, mutually protected type, the factors remain the same, it is the application of the elements of articulation which change, the degree and type of contact. He lists the factors as the following :-

1. Hinge axis
2. Centric relation
3. Condyle path curvature and inclination
4. Bennet movement
5. Anterior guidance
6. Plane of occlusion
7. Curve of Spee
8. Curve of Wilson

Ramfjord & Ash (1983) stress the importance of mandibular movements and occlusal morphology. They state cusps, fossae, grooves and ridges should be compatible with functional and parafunctional mandibular movements. They qualify this statement by pointing out there is no acceptable way to determine functional or parafunctional movements of the mandible that completely describes the relationship between these movements and the occlusion. Also functional occlusion ought to be determined on the basis of mandibular movement of a degree necessary or possible for an individual patient. Kesling (1991) places the emphasis on the hinge axis as being the most important factor for orthodontics. He suggests as does Kunkemoeller (1991) that an ideal gnathologic set up can be carried out for an individual as long as the correct hinge axis is used. Stockli (1981) states that because the maxillomandibular relationship must be determined independent of tooth contact, the choice of applicable methods is very limited. In this context only one method should be discussed: the use of the terminal hinge axis as a reference for:-

diagnostic purposes;

for continuous assessment during treatment;

for evaluation at the end of active treatment and during and after retention.

ELEMENTS OF ARTICULATION

1. Hinge axis - study of the hinge axis has occupied many distinguished workers over a number of years. From Campion (1902) who produced one, if not the first graphic record of mandibular movements on a patient. The slope of the condylar path was demonstrated in different individuals. He concluded "there is and can be no one axis about which the mandible moves in opening the mouth, but that the movement is a complex one, consisting first of a rotation of the bone on an axis passing approximately through the centres of the two condyles, and secondly of a forward and downward movement of the condyles as they slide over or with the meniscus shaped interarticular cartilage along the curve of the eminentia articularis." Bennet (1908) produced his classical paper and stated that no single fixed centre of rotation for the mandible existed since the centre of rotation constantly shifted. He agreed with Campion the mandible was capable of two independent movements - angular rotation about the condyle and translation produced by gliding of the condyle. Gysi (1910) presented a treatise on the history of articulators and how one could determine the

slope of the condyle path. Needles (1927) again came to the same conclusion as Bennet and Campion and stated with regard to studying mandibular movement the logical way would be to divide it into two elementary components. With regard to the axis of the opening movement the articulator could be opened a considerable distance without producing any error. Stansbury (1928) was dubious about the value of facebows and adjustable articulators. He thought that since the opening movement took the teeth out of contact, the use of these instruments was ineffective except for the arrangement of teeth in centric occlusion. McLean (1937) says "when occlusions are synthesised on articulators without accurate hinge-axis orientation there may be minor cusped conflicts which must be removed by selective spot grinding. McCollum (1939) was a leading advocate in the "hinge axis" theory, he was convinced that an opening and closing centre of the mandible was the most important factor in dental articulation. He demonstrated that external landmarks were of little use in location of the hinge axis and was quite satisfied that the mouth could be opened by as much as one half inch in the incisor region in every individual without the condyle heads moving forward in the fossa. Not only did McCollum find great variation of the anatomical centre of the condyle from subject to subject, but also found great variation of the condyles on opposite sides in the same subject. Branstad (1950) looked at function in relation to periodontal disease and decided "an adjustable articulator was as important in oral diagnosis as a microscope was in pathological or bacteriological investigation." His ideas on jaw movements and articulators were essentially that of the Gnathological Society of California. Granger (1954) stated "functional movements of the mandible started and ended at centric relation. Correct orientation of the teeth in centric occlusion, therefore depended upon the correct relationship of the teeth to the hinge axis recorded with the teeth oriented to one another in the most retruded position of the mandible." Lerao (1955) found that the Arcon type of articulator gave a constant relationship between the upper member and the occlusal plane, making the reproduction of mandibular movements more accurate. He as did Beck & Morrison (1956) found there is a possibility of incorporating multiple errors into articulators of complex design because of the increased number of measurements and adjustments. The total of these errors may exceed the errors introduced by assigning fixed values to some adjustments. Posselt (1957) found that the hinge axis passed through both condyles and in summation found that dentists were interested in the terminal hinge movement not because they see it as happening in normal function, but because the pure hinge component can be isolated and used as a landmark for jaw registration and can be reproduced on an articulator. Weinberg (1959) closely studied the hinge axis and agreed with Posselt that it is of clinical importance to orient the maxillary cast on the articulator and allow accurate transfer of the centric relation record. Ramfjord & Ash (1971) stated that hinge axis movement in the temporomandibular joint could occur and the position of the mandible was dictated by the ligaments and structures of the temporomandibular joint hence the ligamentous position.

2. Centric Relation - The jaw relation when the condyles are in the most posterior, unstrained position in the glenoid fossae at any given degree of jaw separation from which lateral movement can be made. With regard to occlusion it is the centred contact position of the occlusal surfaces of the mandibular teeth against the occlusal surfaces of the maxillary teeth. Lucia (1979) tells us in over 90% of normal healthy

mouths, centric occlusion does not coincide with centric relation. The three main reasons to use centric are given as :-

a) it can be repeatedly duplicated during treatment;

b) it is readily acceptable by every patient free of temporomandibular disease without the need for an adjustment period and;

c) it is mechanically impossible to have the correct paths of travel of the cusps if the paths do not start from the centric relation position.

The clinically determined rest position is often situated outside the field of minimum muscle activity - it has been shown electromyographically that in order to obtain balanced resting muscle activity in persons with occlusal interferences, it is often necessary to open the jaws beyond the clinical rest position.

3. Condyle Path Curvature and Inclination - The angle of inclination of the condylar guidance to an accepted horizontal plane, normally the Frankfort plane. The condylar path is determined by the distal slope of the eminence with the synovial membranes and meniscus interposed. In addition to this angle, the condylar path also has a curvature. The inclination affects the contacting surfaces at extremes of articulation and the curvature of the condyle path affects the contacting surfaces between the extremes of centric relation and eccentric relations. Steep condylar paths lead to a rapid disclusion of the posterior teeth in protrusive and lateral movement. This allows far greater clearance of teeth early on in jaw movement. It must be remembered the condylar path in a protrusive excursion is usually different from the path in a lateral excursion. Only a fully adjustable articulator will duplicate these paths without changing the settings.

4. Bennett Movement. - is the lateral bodily motion or displacement of the mandible in lateral movements. It may be immediate or progressive. That is outward motion of the working condyle may begin before its rotational movement or may be combined continuously with the rotational motion of the working condyle. This movement is also known as side shift and not only varies from patient to patient but also from one side to the other in the same patient. The Bennett movement can only be negated by rendering the teeth cuspless.

5. Anterior Guidance. - is made up of horizontal (overjet) and vertical (overbite) relationship of the anterior teeth. It is an angle formed by the incisal edge of the lower anterior teeth and the lingual anatomy of the upper anterior teeth. It works or should work in conjunction with the condylar inclination. Ramfjord and Ash (1983) tell us there is little correlation between the anterior guidance and condylar inclination in most normal patients.

6. Plane Of Occlusion. - is an imaginary surface which is related anatomically to the cranium and which theoretically touches the incisal edges of the incisors and the tips of the occluding surfaces of the posterior teeth. The more parallel the occlusal plane to the condylar path the lesser the disclusion obtained than if the two planes had been divergent. Instead of a flat surface the plane of occlusion represents the average curvature of the occlusal surface. The curvatures of the anterior teeth are determined by establishment of the aesthetically correct smile line on the upper and the relationship of the lower incisal edges to the anterior guidance. The curvature of the

posterior plane into an antero-posterior curve (of Spee, No 7.), and a medio-lateral curve (of Wilson, No 8.).

7. Curve of Spee. - The antero-posterior curvature of the occlusal alignment of teeth beginning at the tip of the lower canine and following the buccal cusps of the natural premolars and molars, continuing to the anterior border of the ramus as described by Graf von Spee in 1906. The curve results from variations in axial alignment of the lower teeth. To align each tooth for maximum resistance to functional loading, the long axis of each lower tooth is aligned nearly parallel to its individual arc of closure around the condylar axis. This requires the last molar to be tilted forward at the greatest angle and the forward teeth to be at the least angle. This progression positions the cusp tips on a curve that is directly related to the condylar axis by a progressive series of tangents.

8. Curve of Wilson. - Is the medio-lateral curve that contacts the buccal and lingual cusp tips on each side of the arch. It results from inward inclination of the lower posterior teeth making the lingual cusps lower than the buccal cusps on the mandibular arch, the buccal cusps are higher than the lingual cusps on the maxillary arch because of the outward inclination of the upper posterior teeth. The two main reasons given for this inclination are:-

i) resistance to loading - the axial alignment of the posterior teeth as said to be nearly parallel with the strong inward pull of the internal pterygoid muscles. The aligning of both upper and lower posterior teeth with the principle direction of the muscle contraction produces the greatest resistance to masticatory forces and creates the inclinations that form the Curve of Wilson.

ii) masticatory function - because the tongue and the buccinator complex must repetitively place each bite of food onto the occlusal surfaces for mastication, there should be easy access for the food to get to the occlusal table. The inward inclination of the lower occlusal table is designed for direct access from the lingual with no blockage by lower lingual cusps. It is also suggested the outward inclination of the upper occlusal table provides access from the buccal side for food to be forced directly onto the occlusal table by the action of the bands of the buccinator muscle.

This is important in function and has implications with the notion of an immediate Bennett or side shift. Classically the condyle/disc assembly prevents the mandibular teeth from travelling medially without first moving downward, this prevents a balancing incline interference. Dawson (1989) states if there is an immediate side shift which allows the condyles to translate horizontally before any rotation occurs the curve of Wilson would result in balancing incline interferences. The only cure for this he suggests is severe alteration of the articulating surfaces. The presence of severe wear on upper lingual cusps should suggest adaptive changes in the articular surfaces of the joint and presence of a Bennett movement. He emphatically states that this type of wear cannot happen in a correct occlusal plane with normal, healthy temporomandibular joints.

The intercondylar distance influences the position and direction of ridge and groove placement. The greater the intercondylar distance, the more distal must be the placement of the ridges and balancing (idling) grooves on the mandibular teeth, and the more mesial must be the placement on the maxillary teeth.

CHAPTER 7: IDEAL TOOTH POSITIONS AND CONTACTS

Roth (1981 c) and Andrews (1976) state orthodontists tend to look at teeth collectively rather than individually. They maintain one needs to know exactly where we would like to have each tooth in each individual case. Andrews defined his best arrangement in his "Six Keys to Normal Occlusion". Roth goes a step further and lists 18 specifics to define tooth by tooth requirements of an ideal occlusion.

1. Lower incisors at the cephalometric goal (+1 to A-Po); for facial aesthetics, for planning anchorage control, and for selecting the most appropriate mechanics to reach this goal.
2. Tips of the upper incisors 2-2.5mm below the lip embrasure of the upper and lower lips, when the lips are closed with no lip strain.
3. No more than 1mm of attached gingiva showing upon a full smile.
4. Approximately a 2.5mm overjet-overbite relationship at the tip of the upper incisor in its relationship to the lower incisor. (The lower incisor would have .0005" clearance with the lingual surface of the upper incisor, but the articulating paper mark would occur 2.5mm gingival to the incisal edge of the upper incisors.)
5. A level or nearly level occlusal plane at the end of appliance therapy that would return to a 1 to 1.5mm curve, at its deepest point, after appliance removal and settling of the occlusion.
6. A Curve of Wilson that would allow seating of centric cusps, but clearance upon excursions.

7. As much divergence as possible of the occlusal plane from the angle of eminence for excursive clearance.

8. Lower incisors aligned contact point-to-contact point with the roots in the same plane, when observed from the occlusal, and a mesioaxial inclination of 2 degrees.

9. Lower cuspid crowns angulated mesially 5 degrees, with the incisal tip 1mm higher than the incisal edge of the lateral incisors. The lower cuspids should have a slightly exaggerated mesial rotation on extraction cases.

10. The lower bicuspids should be uprighted 1 degree from their normal mesial inclination and should have a slight distal rotation (more so on an extraction case). The contact point should be adjacent to the contact point on the lower cuspid distal surface.

11. The lower molars should be uprighted 1 degree from their normal 2 degree mesial inclination, and should have a slight distal rotation.

12. The lower buccal segment should have progressive torque close to Andrews' measurements for establishing the curve of Wilson, and there should be no rotations or spaces.

13. The upper six-year molars should have sufficient distal rotation, mesio-axial inclination, and buccal root torque, so as to fit with the lower six-year molars, as described by Andrews. The same would follow for the upper second molars. The torque requirement would be what is required for the seating of the centric cusps, approximately 14 degrees torque and 0 degrees mesial inclination.

14. The upper bicuspids should be uprighted to 0 degrees from their normal 2 degree mesial inclination, with no rotation, except for some distal rotation in an extraction case.

15. The upper cuspid must have its contact points adjacent to the contact points of the upper bicuspid and lateral incisor, to establish proper length for cuspid guidance. It should have 11 to 13 degrees of mesial crown tip, and mesial rotation of 4 degrees, on an extraction case.

16. The upper lateral and central incisors should be almost equal in incisal edge length, with no more than 0.5mm height differential. They should have 9 degrees and 5 degrees mesio-axial inclination respectively, and there should be sufficient torque so that the six upper anterior teeth can contact the six lower anterior teeth and the upper cuspids can lift off the lower bicuspids in a protrusive excursion.

17. There should be no rotations (other than those for overcorrection) or spaces in the upper arch, and the buccal segments from the cuspids distally should have 14 degrees non progressive buccal root torque.

18. The arch form should be a modified catenary curve consisting of five separate radii - one for the front of the arch form, one for each cuspid-bicuspid area and one for each buccal segment from the first bicuspid distally. The widest point of the lower arch would be at the mesiobuccal cusp of the mandibular first molars and at the first bicuspids. The widest point of the maxillary arch would be at the mesiobuccal cusps of the first molars.

Having done this he states the "heart" of a good result will eventuate, then he demands we keep a mental image of the desired end product at all times during treatment. The objective being to apply brackets, wires or mechanics that will not interfere with ones' ability to achieve the fine details desired. At the end of therapy most orthodontists agree that patients will bite where their teeth fit, and not where they don't. So when we look in the patient's mouth we see the patients neuromuscular adaptation of closure and movement to the existing occlusal arrangement.

Roth (1981c) tells us the prime objective of a gnathologic occlusion is to obtain a stable centric relation of the mandible and have the teeth intercusp maximally at mandibular position. All centric stops should hit equally and simultaneously and the stress of the closure should be directed, as nearly as possible, down the long axis of the posterior teeth. Gnathologically it is stated the important relationship of the maxillary to mandibular teeth is between the centric or supporting cusps and their antagonists. The centric or supporting cusps of the occlusion are the maxillary lingual cusps and the mandibular buccal cusps. There is still debate as to how and where these cusps should fit in an ideal relationship. In the "one tooth to two teeth" arrangement, the relationship is normal if all the maxillary buccal cusps interdigitate between the mandibular buccal cusps in an Angle Class I relationship. Some gnathologists feel if the occlusal stops of central cusps of opposing teeth occlude with adjacent marginal ridges instead of their respective fossae, there is some risk of creating a plunger-like action that will wedge food into contact points between adjacent teeth. Because of this, those gnathologic groups have created the concept of a "one tooth to one tooth" occlusion or a slight Class II relationship of buccal segments to ensure a cusp to fossa relationship of opposing teeth. This allows each centric stop to be surrounded by three opposing triangular ridges, thus offering tripodisation to stabilise and hold centric in restorative or equilibration cases.

Stuart (1964) stated there is a mesial limit of good occlusion, "tooth to tooth" or cusp-fossa occlusion and a distal limit of good occlusion "the tooth to two tooth" or cusp-embrasure occlusion. The gnathologist according to Roth (1976), Lucia (1979) strive to preserve the dentition in a healthy comfortable state. This is done by harmonising tooth structure, occlusal form and tooth position with various border movements of the mandible so that there is minimal need for adaptation by the neuromuscular mechanism. The majority of gnathologists therefore aim for a mutually protected occlusion. Roth (1976) states the attributes of occlusion and articulation that represent this ideal are as follows : -

i) Centric occlusion or maximum intercuspation of the teeth should occur with the mandible in centric relation.

ii) This centric relation occlusion should have a three point contact of the opposing cusps in their respective fossae and lighter occlusal stops for the opposing anterior teeth.

iii) The occlusal force during closure should be of equal magnitude for all posterior teeth, and the stress should be directed along the long axes of the teeth. (The centric stops of the posterior teeth will protect the anterior teeth from lateral stress.)

iv) The relationship of maxillary to mandibular teeth **can** be of the Class I relation described by Angle, **but** a one tooth to one tooth arrangement of the centric cusps (maxillary palatal and mandibular buccal cusps) is more ideal in restorative work.

v) There should be minimal but sufficient anterior overbite to accomplish anterior guidance so that in any excursion outside of centric relation the anterior teeth will be able to function with each other in the full range of patterns and will serve to disclude the posterior teeth approximately 1mm. (the anterior teeth thus protect the posterior teeth from lateral stress.)

vi) In straight protrusion the maxillary six teeth should articulate equally and evenly with the mandibular six anterior teeth and the mandibular first bicuspids, and all other posterior teeth should be discluded.

vii) In lateral excursions the maxillary canines should act as guiding inclines to disclude the teeth on the balancing or non functioning side and to disclude the teeth on the working or functioning side after approximately 0.5mm of group contact.

viii) Tooth structure, tooth position and occlusal form should correlate perfectly with mandibular border movements, including the Bennett movement and immediate side shift, so that on any mandibular excursions cusps will always pass through grooves.

At this juncture it is prudent to recall the words of Rubin (1969) "Neither the perfect patient nor the perfect orthodontic appliance exists, and to plan treatment as if either does, invites a high degree of failure." The above though is a desirable treatment goal to strive for as an ideal, and as Roth (1976) continues to point out in order to assess a patients occlusion from this standpoint it is necessary to resort to more than just a static appraisal of the tooth alignment.

Stallard and Stuart (1963) list only seven main features in their paper, "What kind of occlusion should recusped teeth be given?"

1. Each upper lingual cusp occludes in a fossa of its lower fellow.
   Each lower buccal cusp occludes in a fossa of its upper fellow.
   The lower cuspids and the lower incisors occlude in the fossae of upper cuspids and upper incisors, respectively.
2. All the lower teeth close evenly against the upper teeth at the same time about the transverse intercondylar axis when it is in its rearmost position.
3. In the lateral diagnostic positions of the jaw only the opposing cuspids make contacts. In the lateroprotrusive diagnostic test positions the lateral incisors may also enter into contacts along with the cuspids.
4. In the pure protrusive diagnostic closure the lower six anterior teeth make contacts with the upper incisors; and, the lower first premolars' buccal cusps may touch the tips of the upper cuspids.
5. The fit of the cusps in fossae should be such that the lower teeth reach centric closure and come to dead stops without any slidings beyond or without having skidded on opposing teeth on the way.
6. The plural cusped teeth make occlusal contacts in the centrically related closure but none in the eccentric jaw positions.

7. The multicusped teeth are arranged by occlusion and alignments so that the lower lingual marginal occlusal edges and the upper buccal marginal occlusal edges have no contacts in the centric closure or in the eccentric positions of the mandible during the chewing strokes.

In essence Stallard and Stuart maintain to have a good occlusion, the cusps must be workable yet allow the muscles of the gnathic organism to rest. They continue to accept the necessity for variations, stating as does Roth (1976) that exemplary dentitions vary widely in many features such as arch width, arch length, curvatures of their cuspal curves, in the slant of their occlusal plane, in tooth postures, in facial and cranial relations and in details of intercuspations. Here they point out they find it much easier to work to a cusp-fossa relation, (Stuart's mesial limit of good occlusion) as each plural-cusped tooth has but one antagonist. They find it "not abnormal if each buccal tooth occludes with two opponents." Roth (1976) states the Class I relationship of the buccal segments allows the opposing cusps to pass between each other upon lateral movement.

Natural Pattern Of Centric Contact.

(Tooth-Two-Tooth)

Location of Contacts.

Central Incisors: Incisogingivally the lower central incisor contacts the lingual surface of the maxillary central incisor ideally in the middle one-third. This location may vary from the cingulum to the incisal edge. Mesially the mesioincisal corner of the lower central contacts the mesial marginal ridge of the upper central, and the distoincisal third contacts at about the mid centre of the upper lingual fossa. With wear there may be a continuous line of contact along the labioincisal angle of the lower central and the lingual surface of the upper central. This is a tooth to tooth relationship for the lower central incisor.

Lateral Incisors: Incisogingivally the lower lateral incisor ideally contacts the lingual surface of the maxillary central incisors in the middle one third. This location may vary from the cingulum to the incisal edge. Mesiodistally the mesioincisal corner of the lower lateral incisor contacts the distal marginal ridge of the maxillary central incisor. The middle third of the incisal edge of the lower lateral incisor contacts the mesial marginal ridge of the maxillary lateral incisor. This is a tooth two tooth relationship.

Canines: Incisogingivally the lower canine ideally contacts the lingual surface of the maxillary lateral incisor and canine in the middle one third. This location may vary from the cingulum to the incisal edge. Mesiodistally the prominent mesioincisal corner of the lower canine contacts the distal marginal ridge of the upper lateral incisor, and the cusp tip or distal arm of the lower canine contacts the upper canine on its mesial half.

First Premolars: Buccolingually the lower first premolar interdigitates with its buccal cusp in the central groove zone of the upper first premolar. The lingual cusp of the upper first premolar occludes in the central groove zone of the lower first premolar. Mesiodistally when viewed from the buccal, the lower first premolar is positioned between the upper canine and the first premolar which characterises the tooth two tooth occlusion. Ideally the buccal cusp tip of the lower first premolar contacts the centre of the mesial marginal ridge of the upper first premolar. Within normal limits this contact may vary from the distal marginal ridge of the upper canine to the mesial pit of the first premolar. The lingual cusp tip of the upper first premolar ideally contacts the centre of the distal marginal ridge of the lower first premolar. Within normal limits this contact may vary from the distal pit of the lower first premolar to the mesial marginal ridge of the lower second premolar. It is also suggested that by virtue of their being the first multicusp teeth in the arch the first premolars provide the potential for initiating the lingual range of centric contacts. It is not often the case owing to the small nature of the lower first premolar cusp.

Second Premolars: Buccolingually the buccal cusp of the lower second premolar interdigitates in the central groove zone of the upper second premolar. Mesiodistally when viewed from the buccal, the lower second premolar is positioned between the upper first and second premolars. Again a classic example of the tooth two tooth occlusion. Ideally the buccal cusp tip of the lower second premolar contacts the centre of the mesial marginal ridge of the upper second premolar. Within normal limits this contact may vary from the distal marginal ridge of the upper first premolar to the mesial pit of the upper second premolar. The lingual cusp of the upper second premolar contacts the centre of the distal marginal ridge of the lower second premolar. Normal variation is from the distal pit of the lower second premolar to the mesial marginal ridge of the lower first molar. The buccolingual and mesiodistal half tooth stagger or zigzag in the pattern of posterior centric contact now becomes apparent.

The tooth-two-tooth contact makes it appear that the lower facial cusp tips are interposed in the opposed occlusal embrasure and that the cusp arms contact both of the adjacent marginal ridges. Such a wedging contact is deemed undesirable and stable contact should be sought on one or other of the marginal ridges.

First Molars: Buccolingually the buccal cusps of the lower first molar contact in the central groove zone of the upper first molar. The upper first molar lingual cusps contact in the central groove zone of the lower first molar. Mesiodistally the mesiobuccal cusp of the lower first molar interdigitates between the upper second premolar and the first molar. Ideally the lower mesiobuccal cusp contacts the mesial marginal ridge of the upper first molar. Acceptable variation is from the distal marginal ridge of the upper second premolar to the mesial pit of the upper first molar. While contact of lower buccal cusps which interdigitate between adjacent upper teeth should contact one or other of the marginal ridges. The mesiobuccal cusp of the lower first molar often contacts both the mesial marginal ridge of the upper first molar and the distal marginal ridge of the second premolar as it tends to be a very wide blunt cusp. The distobuccal cusp of the lower first molar contacts in the central fossa of the upper first molar and interdigitates between the buccal cusps of the upper molar. It may vary from the junction of the triangular ridges of the upper first molar mesial cusps to its oblique ridge.The distal cusp of the lower first molar may or may not provide a centric contact. When it does, this contact will ideally occur on the distal marginal ridge of the upper first molar. It can vary between the distal pit of the upper first molar and the mesial marginal ridge of the upper second molar.The mesiolingual cusp of the upper first molar contacts in the central fossa of the lower first molar and interdigitates between its lingual cusps. It may vary within normal limits from the junction of the triangular ridges of the lower mesial cusps to the junction of the ridges of the distal and distolingual cusps.The distolingual cusp of the upper first molar contacts the distal marginal ridge of the lower first molar. Within normal limits this contact may vary between the distal pit of the lower first molar and the mesial marginal ridge of the lower second molar.

This makes a total of five potential centric holding contacts between the first molars. Two of these contacts occur from cusps occluding in the central fossa of the opposing molar - the upper mesiolingual cusp and the distobuccal cusp. Three buccal range contacts on each of the buccal cusps and two lingual range contacts. The interdigitation of the upper mesiobuccal cusp in the buccal groove of the lower first molar is the posterior key or landmark in determining Angle's classification of occlusal relationship.

Second Molar: Buccolingually the buccal cusps of the lower second molar interdigitates in the central groove zone of the lower second molar. The lingual cusps of the upper second molar contact in the central groove zone of the lower second molar. Mesiodistally the mesiobuccal cusp of the lower second molar interdigitates between the upper first and second molars providing the characteristic tooth two tooth relationship. Ideally the tip of the lower mesiobuccal cusp contacts the mesial marginal ridge of the upper second molar. Normal limits for this contact may vary from the distal marginal ridge of the upper first molar to the mesial pit of the upper second molar. The distobuccal cusp of the lower second molar contacts in the central fossa of the upper second molar. Again normal variation is from the junction of the triangular ridges of the mesial cusps of the upper molar to its oblique ridge. The mesiolingual cusp of the upper second molar contacts in the central fossa of the lower second molar. Normal limits for this contact may vary from the junction of the triangular ridges of the mesial cusps to the junction of the ridges of the distal cusps of the lower second molar. The distolingual cusp of the upper second molar contacts the distal marginal ridge of the lower second molar. Within normal limits this contact may vary from the distal pit of the lower second molar to the mesial marginal ridge of the third molar if present.

So for the second molars there is a potential for four holding contacts - two buccal range and two lingual range. The lower second molar interdigitates in the mesiodistal plane in the usual tooth two tooth relationship whilst the upper second molar opposes only the lower second molar when the third molars are not present, leaving in a tooth to tooth relationship.

Variation in the third molar is quite common and contact relationships have not been considered. Lucia (1969) is of the opinion for an occlusion to be gnathological, one needs it to be a bilaterally balanced occlusion as just described, or a cusp to fossa mutually protected type as I shall describe next. This occlusion he states was first taught by Thomas and Stuart, and fully endorsed by Stallard. The important characteristic of this is said to be all cusps are nestled in fossae, there are no cusp to marginal ridge relationships to cause any opening of contacts and closing forces are all dissipated in the long axes of the teeth. Or as Lucia describes it "each upper and lower tooth becomes locked as one pillar when the jaws are in centric relation - they support each other."

Cusp-To-Fossa (Tooth-To-Tooth)

Location Of Contacts

The centric relation contacts are described as follows. The incisors should miss contact by a very small amount Williamson (1976) tells us two thicknesses of 0.0005 mylar paper should meet some resistance when pulled from between the incisors.

Canines: The mesiolingual surface of the upper canine contacts the distobuccal surface of the lower canine. The distolingual surface of the upper canine contacts the mesiobuccal marginal ridge of the lower first bicuspid.

First Premolar: The buccal triangular ridge of the upper first premolar crosses and makes contact on the buccal surface of the distal slope of the buccal marginal ridge of the lower first premolar. The lingual triangular ridge of the upper first premolar contacts the inner aspect of the distobuccal marginal ridge of the lower first premolar. The buccal triangular ridge of the lower first premolar contacts the inner aspect of the mesiolingual marginal ridge of the upper first premolar. The lingual triangular ridge of the lower first premolar contacts the lingual side of the side of the mesiolingual marginal ridge of the upper first premolar. The mesial marginal ridge of the upper first premolar crosses and contacts the mesiobuccal marginal ridge of the lower first premolar. The distal marginal ridge of the lower first premolar crosses and contacts the distal portion of the lingual marginal ridge of the upper first premolar.

Second Premolar: The contacts between the upper second premolar and the lower second premolar are said to be exactly the same as those of the first premolars with one exception:- when there are two lingual cusps on the lower second premolar, the contact is made between the triangular ridge of the distolingual cusp and the lingual side of the mesial portion of the lingual marginal ridge of the upper second, premolar.

First Molars: The triangular ridge of the mesiobuccal cusp of the upper first molar crosses and contacts the distal slope of the marginal ridge of the mesiobuccal cusp of the lower first molar. The triangular ridge of the mesiolingual cusp of the upper first molar crosses and contacts the triangular ridge of the mesiobuccal cusp of the lower first molar. The oblique ridge of the upper first molar runs from the distobuccal cusp to the mesiolingual cusp and is divided by the mesiodistal central groove. The buccal portion (on the distobuccal cusp) contacts the groove between the buccal and distobuccal cusps of the lower first molar. The lingual portion of the oblique ridge (on the mesiolingual cusp of the upper first molar) crosses and contacts the triangular ridge of the buccal cusp of the lower first molar. The triangular ridge of the distolingual cusp of the upper first molar crosses and contacts the triangular ridge of the distobuccal cusp of the lower first molar.

The mesial marginal ridge of the upper first molar crosses and contacts the mesial slope of the marginal ridge of the mesiobuccal cusp of the lower first molar. The distal marginal ridge of the upper first molar crosses and contacts the distal slope of the marginal ridge of the distobuccal cusp of the lower first molar. The triangular ridge of the mesiolingual cusp of the lower first molar contacts the mesial portion of the lingual surface of the lingual marginal ridge of the mesiolingual cusp of the upper first molar (the cusp of Carabelli).The triangular ridge of the distolingual cusp of the lower first molar crosses and contacts the lingual surface of the lingual marginal ridge of the upper first molar as the marginal ridge dips from the mesiolingual cusp to the distolingual cusp.

Second Molars: The contacting surfaces of the upper and lower second molars in centric relation are said to be the same as those of the first molars by Lucia (1969).

CHAPTER 8: ARTICULATORS WITH REGARD TO ORTHODONTICS

The premise that is quite often used in orthodontics is "the mouth is the best articulator" is not always true. With occlusal disharmony, when a patient brings his teeth together all the force of the bite is concentrated in a small area, often causing pain and trauma to the interfering tooth and its periodontal structures. This in turn causes the muscles that move the mandible to try to create a pathway to avoid the prematurity and allow the teeth to contact more evenly. This is known as a neuromuscular avoidance pattern or functional shift which is of course an involuntary action. An attempt to mark the prematurity with articulating paper is not always successful due to the subconscious desire to avoid the contact.

To investigate the occlusion further one needs to mount casts of the patient's teeth on an adjustable articulator, this can only be done after resolving the muscle splinting with a form of bite splint and then recording the "bite." In other words if the occlusion is not in harmony with the temporomandibular articulation, the response of the musculature will be to move the mandible according to the dictates of the occlusion and not the joints. (Ramfjord & Ash 1983) and Roth (1981) states if the degree of conflict between the movements dictated by the teeth and those dictated by the joints is great enough to surpass the individuals tolerance, trouble usually ensues.

It is for this reason it is necessary to have a device that will give a good idea, or measure of the individualised occlusal scheme that will work best in a given case. This machine is an articulator, or as it was once described by Lucia (1979) "an amazing and confusing array of beautifully machined nuts and bolts." The articulator is an attempt to eliminate the neuromuscular response of the patient so that one can see how the teeth relate to the mandibular border movements. Mathews (1967) tells us common usage of modern articulators is made in mounting casts on the so-called terminal hinge axis to establish a base line in simulating functional jaw movements. This has become known as centric relation. Sicher (1956) tells us it is a dynamic biomechanical concept. "Centric relation is best described as the ideal, totally harmonious or balanced occlusal position, in which not only all the teeth are in proper contact but also the joints and their muscles are in equilibrium." This is in contrast to the more rigid descriptions once in common use, such as, "the most retruded, unstrained position or rearmost, uppermost midmost position." Centric relation unfortunately is ordinarily a strained position and does not represent a physiologic relation of the jaws in most individuals. Normal function is not carried out at extreme ranges of motion, in short this most retruded, strained peripheral position is unlikely to be home base from a functional point of view. As Lucia (1979) points out, in 90% of normal healthy mouths centric relation and centric occlusion do not coincide. The most obvious reason for building an occlusion in centric relation is because it is prosthetically convenient. It is the only relation that can be repeatedly duplicated during treatment.

This might explain why Mathews (1967) tells us "It is reported that centric relation was defined by the prosthodontists, mechanised by articulators, discussed at great length by periodontists, redefined in oral rehabilitation and ignored by orthodontists. "An articulator according to the Glossary of Prosthetic Terms 1977 is a device for mounting either diagnostic models or working model for constructing prostheses. Static hand held models as we have discussed are only good for a macroscopic view of the overall archform and shape, giving little indication to the interplay between the teeth in dynamic function. It must be noted that some articulators are capable of imitating mandibular movement more precisely than others, but all articulators fail to represent the functional mechanism in its entirety. In essence therefore the objective of articulators is to serve as a laboratory aid in imitating physiologic motion by substituting mechanical equivalents for anatomical parts. Weinberg (1963).

There are many articulators on the market. Barnett (1984) has a simple classification of three groups:-

1. Non-Adjustable
2. Semi-Adjustable
3. Fully-Adjustable

Non-adjustable. These are essentially a simple hinge mechanism, or average value articulator. Some are capable of lateral and protrusive movements and are of an "anatomical size." They do not accept a facebow record. The angles at which the condyles move are fixed according to average values. (Howat, Capp & Barnett 1991)

Semi-adjustable. These are the most widely used for both diagnostic and treatment procedures. They are designed to be of an anatomical size, their intercondylar distance being similar to that in the "average" patient, but usually without the capacity for adjustment. Barnett (1984) limits his examples of the semi adjustable articulators to the non-arcon articulators. Arcon (**ar**ticular-**con**dyle) more closely represent the anatomical relationships in having their condyles on the lower member and fossae on the upper. It is said by Tanaka and Beu (1975) that it helps in the understanding of mandibular movement and produces a more constant condylar path as the guides remain constant to the movement of the upper member. Howat, Capp and Barrett (1991) also advocate the use of arcon semi-adjustable articulators. The semi-adjustable articulators are adjustable to individual static records. The patients Bennett movement is recorded efficiently with lateral interocclusal records. However the patients sagittal angulation of the balancing condyle is assumed to be similar to the protrusive condylar inclination. A semi-adjustable articulator guides only the medial component of the balancing side condylar movement. Dawson (1989) tells us one of the biggest shortcomings of the semi-adjustable articulators is that condylar pathways are limited to straight lines. He points out because of this limitation these instruments are sometimes referred to as check bite articulators.

Fully-adjustable. Should simulate mandibular movement most accurately. This is due to the fact these instruments accept pantographic tracing equipment to determine mandibular behaviour and also have a variable inter condylar distance. One of the simplest according to Dawson (1989) is the T.M.J. articulator. The border movements are recorded in three dimensions by means of intraoral clutches stabilised by a central balancing point. Recordings are made by indenting three or four points in doughy self-curing acrylic rests on the opposite clutch and moving the mandible through its border movements. The acrylic guide paths are allowed to set hard and the condyle paths are made in self curing acrylics as dictated by the indented recordings on the clutch.

Barnett (1984) states from the orthodontic point of view, a fully adjustable articulator may offer more refinement than is necessary for daily occlusal assessment. However if the case is to involve the disciplines of orthodontics, oral surgery and restorative dentistry, a semi-adjustable articulator would be the minimum choice. Wood (1977) says to get the general practitioner, or even the specialist, to use a semi-adjustable articulator would be a step in the right direction. Hohl (1978) also chooses a semi-adjustable articulator, adjustable to the opening and closing movements, the protrusive, right and left jaw positions movements for planning segmental surgery. He contends that fully adjustable articulators are too time consuming and employ needless accuracy that cannot be duplicated in the surgical or orthodontic procedure. Watt (1968) looked at the reproducibility of the fully adjustable articulator settings from graphic recordings of mandibular movement. He concluded the high probability of error in the use of a fully adjustable articulator made it unacceptable as a means of diagnosing occlusal disturbances.

Weinberg (1963) on the other hand came to the conclusion only the gnathologic type reproduces three dimensional guidance of the working condyle and is the instrument of choice. Winstanley (1977) takes the moderate's point of view in so far as his study showed that most of the fully adjustable articulators were able to reproduce jaw movements with a reasonable degree of accuracy, although not quite to the extent he would have liked. Thurow (1977) is much in agreement he cautions that the technical refinement of articulators has reached a level of precision that far exceeds the accuracy that can ever be achieved at the vital patient instrument interface. His three main criticisms of articulators was:-

i) there is no way a hard round ball can provide any more than a rough approximation to the flattened ovoid cylinder that forms the head of the condyle. The complexity and resiliency of the joint capsule is also lost.

ii) plaster casts do not produce the natural mobility of the individual teeth that is provided by the periodontal membrane;

iii) serial analysis is extremely difficult and rarely undertaken. From the orthodontic point of view the dynamic nature of dental articulation with its ongoing changes throughout life is lost.

The latter is also a point Moss (1975) makes, he claims that in a short period of time the dynamically fluctuant state of the neuromuscular apparatus makes it reasonably certain that intra-individual variation in the condylar positions can exist. Over relatively long periods of time the morphology of all functional surfaces of the temporomandibular joint is capable of significant adaptive change. Mongini (1977) supports this point of view and indicates remodelling of the condyle will alter according to the new occlusal scheme produced by orthodontic or any other therapeutic means.

Bellanti (1973) and Aull (1965) with regard to prosthodontics are much enamoured by the fully adjustable articulator "we will prepare ourselves with instruments and methods for measuring them (condylar movements) in the patient, and recording them in the articulator upon which we will make the occlusal analyses and the corresponding restorations." Chiappone (1975) prefers the use of a fully adjustable articulator in orthodontics. He states the information is exceedingly important in determining crown inclination and angulation of incisors and whether or not the case will have canine guidance or interference.

Roth & Gordon (1981d) also regard an anatomical articulator as essential in orthodontics, primarily for the construction of gnathological positioners. Having stated that they continue by saying it is perfectly acceptable to use a carefully selected estimated axis transfer, and if appliance therapy has brought the case close to the occlusal requirements one may also use an average movement pattern to simulate the movement of the human mandible. Estimated averages for the articular eminence - 30 degrees and a 1mm analogue block for most adults.

Mathews (1967) presents a realistic view point in his article on functional considerations of temporomandibular articulation, he states common usage of modern articulators is made in mounting casts on the so called terminal hinge axis to establish a base line in simulating functional movements of the jaw. He finds no reason to question the need for an articulator in prosthetic dentistry where natural proprioception of the periodontal ligaments of the teeth has been lost. There he finds the reproducible nature of the terminal hinge point a reasonable base line. He thought the more sophisticated articulator has a way of becoming an authority on functional occlusion and warns against moving teeth into preconceived notions of how teeth should function. The result he states may set up a series of altered proprioceptive stimuli from the periodontal ligament which in turn may lead to further problems.

Cottingham (1978) tells us in order to look at articulation of the teeth we should use a "three dimensional cephalometric instrument to measure discrepancies," in other words an articulator. Thompson (1962) is not so enthusiastic stating "tooth relations on the casts are functionally normal only to the degree that they permit normal temporomandibular joint and muscle function without undue stress on the supporting tissues of the teeth during function." He is of the opinion functional analysis can only be carried out on the patient. Stockli (1981) like Cottingham is also quite satisfied the articulator should be used. He states that the maxillomandibular relationship must be determined Independent of tooth contact and one should use the terminal hinge axis as:-

1. a reference for diagnostic purposes,
2. for continuous assessment during treatment,
3. for evaluation at the end of active treatment and during and after retention.

Baltas and Tsellios (1964) warn against using the mouth as a functional articulator. This is because the neuromuscular positioning of the mandible may compensate for occlusal discrepancies and hide the true nature of the malocclusion. Tuverson (1980) recommends that diagnostic set ups be done on articulators, particularly in cases with interocclusal arch length deficiency cases. Perry (1969), Williamson (1976) and Parker (1978) all state that the articulated models may serve as a means of communication between specialities, and between the orthodontist and general practitioner.

CHAPTER 9: CHANGING THE OCCLUSION AND THERAPEUTIC GOALS

Both occlusal rehabilitation and orthodontic treatment are performed to replace disharmony of the occlusion with harmony. In a functional context Moller and Bakke (1988) tell us harmony and disharmony are terms of convenience and they question whether they have any place in relation to physiological or harmful interaction between occlusion, muscle activity and joint function. Nathan, Allan and Shore (1959) on the other hand like the terms and write, "the establishment of a harmonious relationship between the inclined planes of the teeth, the neuromusculature and the TMJ in function is the purpose of occlusal equilibration. Actually the occlusal equilibration may be considered a form of orthodontic therapy."

In the study of craniomandibular disorders occlusion is more often recorded in terms of physical tooth contacts, in intercuspal and eccentric positions and evaluated according to various theories, *e.g.* coincidence of maximal intercuspation and mandibular retrusion, anterior guidance, avoidance of balancing interferences etc. The need for treatment is then based on the assumption that adjustment or finishing the case according to these theories may relieve the muscles of mastication and the temporomandibular joints of psychological or physical stress.

The aim of this thesis is threefold, the major part is devoted to the description of the theoretical standard of occlusion in extraction patterns. These were produced by simulating orthodontic treatments for a number of different extraction patterns. The second part and third parts are discussed in the literature review and revolve about the questions:-

i) Is such a standard justified? Ottolengui (1930) declared that given a particular set of teeth, there is but one arrangement of them that will result in functional occlusion. There is but one position into which each tooth must be placed: there is but one relation of direction which each tooth must bear to its socket, and there is but one occlusal relation that each tooth must have with its antagonists that will result in functional occlusion. To test this ideal he suggests mounting the teeth in an articulator and placing each tooth in a position to attain "the highest efficiency which he believed is the true standard for functional occlusion. He says of this, that probably no effort of the orthodontist could attain this result in a large majority of cases, **but** it is a valuable pattern to serve as a guide in our work. Allowing for this Ottolengui accepts entirely satisfactory results may be obtained without reaching the ideal. However any departure from an ideal position will interfere with functional occlusion and even if it be adequate one must call it functional occlusion plus or minus.

Angle (1907) cited that there was a majesty in the pattern and forms of teeth. He believed that tooth size, form and shape, its position in the arch and the intended fit, individually and collectively was designed for the greatest possible support in all directions. The question really becomes idealism versus biology, Isaacson (1976) wrote of the biological concept of occlusion and finds it presumptuous to establish any ideal for normal. He describes such concepts of the ideal as unproven speculation. Ricketts (1989) on the other hand tells us the understanding of any parameter in the field of health or the life sciences starts with the ideal even if it is only imagined. It is hoped to go one better than pure imagination and produce some therapeutic goals for occlusion.

ii) Does the information gathered only apply to one set of conditions or criteria. As has been pointed out in previous chapters exemplary natural dentitions vary widely in many features; in arch width, in arch length, in the curvatures of their cusps, in the slant of their occlusal plane, in tooth postures, in face and cranial relations, in dentolabial relations and in their intercuspal relations. Stallard and Stuart (1963) tell us any pattern of occlusion that tolerates no variations in details and relations is impossible. Variation is necessary to accommodate a dentition's occlusal elements to the divergencies occurring in the major intermaxillary relations such as centric, lateral and protrusive. So it must be accepted the range of variation is so great that a high degree of individual preference for arranging the teeth is possible. The objectives of treatment according to Ricketts (1989) lies in the three traditional issues in orthodontics namely:-

a) what looks best for the patient (aesthetics)

b) what will be healthy in function and

c) what will remain stable

The general relationship between the maxillary and the mandibular teeth are viewed by seeing how the occlusal surfaces direct and distribute the closure forces. Anterior teeth work as a unit (anterior guidance) to restrict the horizontal movements of the posterior teeth during eccentric excursions. In order to achieve this the torque values of the upper incisors should perhaps be dictated by their palatal surfaces rather than the labial aspect as is the case with the straight wire appliance. When the posterior teeth are functioning properly without mandibular slide, they protect the anterior teeth against excessive horizontal forces in the vertical closure position to produce a mutually protected dentition. Despite an overwhelming support for the occlusion described above Belser and Hannam (1985) concluded in their paper "there is no scientific evidence to indicate that canine guidance or group function are more desirable than any other occlusal scheme. They also mention the steepness of anterior guidance did not seem important, again contrary to popular opinion.

Properly occluded cusps do not deflect or guide the cyclic closure of the mandible. More specifically cusps should not cause lateral or anterior deviation of the jaw upon closure. The occluding posterior cusps, called stamp cusps are the maxillary lingual and mandibular buccal cusps. The maxillary buccal and mandibular cusps that do not occlude in a fossa are called shearing cusps. (Wasson 1987). A fossa receiving a stamp cusp should be nearly midway between the buccal and lingual cusps of the tooth. A stamp cusp should be carried into its fossa and out of it without striking its fellow antagonist except in centric and closure. During working or diagnostic excursions the cusp should leave through a groove. There should be at least one contact on each tooth to offset movement in each direction. Contacts on the mesial slopes of the lower cusps are called closure stoppers, because they stop the mandibular arc of closure against the closure stoppers on the distal slopes of the upper cusps. To offset movement in the opposite direction, each tooth should have an equaliser contact. These are located on the distal slopes of the lower cusps and mesial slopes of the upper cusps. Contacts are also present that offset buccolingual movement. These are the upper shearing cusp (buccal), a lower stamp cusp (buccal) and upper stamp cusp (palatal) to lower shearing cusp (lingual) both of which offset buccal movement of the lower tooth and palatal movement of the upper tooth. The opposing force is produced by the stamp cusp of the upper (palatal) to the lower stamp cusp (buccal) of the lower tooth.

Dawson (1989) tells us upper to lower tooth relationships should be evaluated for direction of stresses, distribution of stresses, and stability. If the occlusal relationship causes stress to be directed favourably up or down the long axes, the first requirement of stability has been fulfilled. If the occlusal contours permit favourable distribution of lateral forces in excursive movements, the second major requirement of stability can be fulfilled.

Tuverson (1980) lists five major objectives of functional occlusion:-

1. minimal (less than 1.5mm) or no slide from C.R. → C.O.
2. even contact on both sides with no lateral slide and no forced mandibular movement.
3. canine protected occlusion on both sides.
4. no balancing interference upon lateral movements.
5. disclusion of posterior teeth in protrusion.

Dawson (1989) has a similar outlook, he tells us there is no one type of occlusal form that is optimum for all patients. The approach ought to be to design each occlusal surface or bite to definitely accomplish specific effects. He divides the objectives between the anterior and posterior teeth and maintains the critical objectives of posterior occlusal contours are as follows:-

A) Multiple equal intensity contacts on each tooth in centric relation at the correct vertical.

B) Occlusal forces directed parallel to the long axis of each tooth.

C) Non-interference with any border path of the condyles or the anterior guidance.

He is however of the opinion anterior guidance is the most important determination that must be made in orthodontic treatment. He feels failure to properly establish the correct guidance is a major cause of post treatment instability. He continues by saying - unfortunately the occlusal problems that result from inadequate anterior guidance are usually slow enough in causing damage that the orthodontist is unaware of the problems or the reason for instability.

Many authors Ramfjord & Ash (1983), McHorris (1989), Roth (1981c), and Chiappone (1975) consider anterior guidance to be of great importance. They tell us anterior guidance or anterior disclusion suggests quite correctly the anterior teeth are the dictating components which control the direction of movement of the mandible. They stress the amount of time that the teeth are in contact during functional activity amounts to only 15-20 minutes each day. Parafunction is a different story and causes attrition, abrasion and excessive wear. The one with potential to render the most damage is bruxism. Nocturnal bruxism (night grinding) is said to be the more damaging than diurnal bruxism (daytime grinding). The force level is said to be ten times greater than those found in functional usage and can occur intermittently from 1-4 hours each night.

McHorris (1989) writes once it is recognised that there is a need for posterior disclusion through the efforts of anterior teeth, we must seek to establish the proper contour; pitch, inclination and overlap of these teeth. The steeper the anterior disclusive angle the more posterior disclusion results. He finds that few patients could tolerate an increase of more than 15 degrees in this anterior disclusive angle. Berry and Watkinson (1978) reported symptoms of mandibular dysfunction in patients who had orthodontic treatment with removable appliances. In these patients it was suggested that retraction and retroclination of upper anterior teeth in the treatment of Class II malocclusions was the cause of this dysfunction as a result of the increasing overbite. Ramfjord and Ash (1983) also stated that clinically there does not seem to be any correlation between condylar and incisal guidance. Should there be a disharmony they thought that tooth movement would allow accommodation to the occlusion rather than adaptive changes to the joint. Again they agreed with Berry and Watkinson (1978) in so far as they found that incisal guidance was commonly made steeper by lingual movement of the maxillary anterior teeth and the cuspal inclination was made less steep by the expansion of the maxillary arch in the bicuspid region.

The requirements of anterior guidance is minimal overbite and sufficient torque of the incisors to allow maxillary canines to lift on the mandibular first bicuspids and a level occlusal plane through to the second molars. If the anterior lift is too severe to allow gliding movements in all directions it will interfere with the mandibular movement pattern.

The position of lower incisors has long been recognised as the first priority in orthodontic diagnosis and treatment planning. Occlusal stability, aesthetics, and space available in the mandibular arch all depend on correct positioning of the lower anterior segment. Dawson (1989) gives five important goals in the positioning of the lower incisors.

1. Aesthetics
2. Phonetics
3. Occlusal Plane
4. Anterior Guidance
5. Stability

In orthodontics the most common measurements for the lower incisors is the angle it makes with the mandibular plane, and in the antero-posterior direction its relationship to the A-Pog line. Wasson (1987) tells us Stuart and Karr looked at its position in relation to the hinge axis and found that the condylar incisor angle (CI); that is the angle between the line from the centre of the condyle to the incisal edge of the mandibular central incisor and its long axis was ideally about 90°. The standard deviation being 5.3° overall and 4° in a Class I skeletal pattern. This demonstrates a much greater consistency than measurement to the mandibular plane angle which Wasson stated is "understandable because this angle is based on a functional rather than a arbitrary relationship."

So in conclusion the general consensus indicates we should be aiming for the following:-

1) Intra arch tooth stability - no spacing

2) Inter arch tooth stability - at least one contact per tooth.

3) Bilateral synchronous jaw contacts in centric occlusion.

4) Excursive guidance as far forward as possible.

The functional aim of modifying the occlusion is to minimise the conflicting peripheral stimulation of the central mastication centre. This is not always achieved by conforming to the "six keys" of Andrews. Important to that concept is that there is a great variation in the adaptive capacity of individuals and changes that are introduced slowly are often tolerated more easily.

CHAPTER 10: INTRODUCTION TO THE EXPERIMENT

Accepting there are no occlusal stereotypes that fit all patients and there are no averages to fit all patients. Four hypothetical patients were manufactured each being a "typical" representative of the four major classifications of malocclusions, Class I; Class II, div 1; Class II, div. 2; and Class III. In the manufacture of these patients gross skeletal imbalances between maxilla and mandible were excluded; a criteria for inclusion was that the malocclusion be amenable for an orthodontic correction. All the patients had in fact been treated at the United Dental Hospital with full fixed banding. The admonition of Solow (1980) is also recalled "all orthodontists are aware of the fact that averages and norms for cephalometric dimensions should not be applied in the individual case. Nevertheless, average values printed on cephalometric measurement forms exert a curious attraction."

CEPHALOMETRICS / JAW RELATIONSHIP

The parameters of the various malocclusions were set as:-

Class I	SNB = 78-80°	ANB = 0-2°;
Class II	SNB $\leq$ 78°	ANB $\geq$ 2°
Class III	SNB $\geq$ 80°	ANB $\leq$ 0°

The expected tooth movement would also be within the envelope of discrepancy dictated by Ackerman and Proffitt (1985) for malocclusions treatable by orthodontics alone.

The cephalometric values for the patients were as follows :-

	Class I	Class II,1	Class II,2	Class III
ANB	2°	6°	2°	0°
WITS	0mm	4mm	1mm	-3mm
Emdl - Emxl	27mm	23mm	29mm	31mm
U1 - SN	107°	99°	108°	112°
L1 - MPI	91°	107°	99°	89°

It is postulated that a hypothetical patient of average measurements/ malocclusions can be used as an arbitrary standard for comparisons. The evaluation is then made on the occlusal standard.

Solow (1980) maintains that "the difference in inter arch relations of Class I, Class II, and Class III malocclusions are probably not directly due to the differences in skeletal morphologies, but rather the fact that in the Class I group, the variation in jaw relationship has been compensated for by the dento-alvelar compensatory mechanism, whereas in Class II or Class III it has not." Bjork and Skeiller (1972) were of the opinion orthodontic treatment should be planned in accordance with the individual pattern of facial growth. As they believed compensatory changes occurred in the paths of eruption of the teeth which tended to even out positional changes between the jaws. They stated that if the compensation were insufficient or did not occur the result would be space anomalies and a defective occlusion.

TEETH.

The teeth chosen were acrylic and manufactured by Formadent. They were chosen as they represented a "normal" or "ideal" tooth in both their morphology and size. The morphology of both the crown and root was compared with those described by Scott and Symons (1964) and A.C. Gabriel (1965) and they were found to conform to the descriptions and illustrations provided.

Characters such as size, shape and fissure patterns of teeth are genetically determined. Scott and Symons (1964) tell us that in the human dentition the most stable permanent teeth and the ones which show the minimum of genetic and racial variabilities are the canines, central incisors and first molars; the most variable are the upper lateral incisors, the second premolars and the second and third molars. The Formadent teeth would appear to show the characteristics of the white races.

With regard to the tooth size they were collectively and individually well within the range given by Lysell and Myberg (1982) who looked at Swedish boys and girls and compared them with the studies of Lundstrom (1954), Seipel (1946), Moyers et al. (1976), Garn et al. (1968), Alvesalo (1971) and finally Moorrees et al (1959). In addition to these Richardson and Malhotra (1975) looked at the permanent teeth of American Negroes, they found them to be slightly larger than those of the other studies mentioned.

The overall Bolton ratio was found to be 91.2 against the mean of 91.3, the anterior ratio being 78.4 against a suggested mean of 77.2 indicating an anterior mandibular tooth size excess of 0.5mm. Well within normal parameters.

Tooth Size

	MAXILLARY			MANDIBULAR		
	Formadent Teeth	Moorees (1959)	Richardson & Mulhotra (1975)	Formadent Teeth	Moorees (1959)	Richardson & Mulhotra (1975)
Central Incisor	9.00	8.78	9.12	5.75	5.42	5.53
Lateral Incisor	6.62	6.64	7.26	6.00	5.95	6.13
Canine	8.00	7.95	8.19	6.75	6.96	7.37
First Premolar	7.12	7.01	7.66	7.00	7.07	7.76
Second Premolar	7.00	6.82	7.25	7.00	7.29	7.85
First molar	10.50	10.81	11.04	11.50	11.18	11.76
Second Molar	9.75	10.35	10.74	10.75	10.76	11.53

BRACKETS, AND THE STRAIGHT WIRE PREMISE.

Andrews (1990) accepts that the straight-wire appliance does not achieve all the expected treatment results. He states a major reason for this is that orthodontists are generally unable to agree on a base line, or referents from which to develop their objectives. He continues "not all patients are treated to the six keys, as the landmarks used for bracketing as well as for communicating with the tooth's occlusal surface are varied and as a consequence produce varied results."

A number of authors have looked at the problem of bracket position Fowler (1990) came to the conclusion that the clinical implications were limited to only minor changes in crown inclination and root apex position. The greatest variable both intra and inter clinician was the long axis of the clinical crown or inclination. He also saw a need to study the effects of varied tooth morphology and level of gingival attachment on the perceived placement of the bracket. Taylor and Cook (1992) did an in vitro study on the reliability of positioning brackets. They too found bracket angulations (long axis of clinical crown) were far less reliable than either vertical or horizontal bracket positioning. They conclude their paper with a recommendation to further investigate a reliable technique for bracket placement. Balut et al. (1992) however were of the opinion that error in bracket placement would lead to unstable tooth position, lack of root parallelling, food impaction because of marginal ridge discrepancies, and a failure to establish the very specific occlusal scheme of canine rise or mutually protected occlusion. This latter comment seems to be well supported by the literature review of Chapter 5. They do however suggest an excellent result can be attained with proper wire bending or rebonding bracket positions.

Assuming then that the bracket can be placed accurately what result can be obtained? Dellinger (1978) applied himself to this question in his paper "A scientific assessment of the straight wire appliance." Or as he begins, How straight is straight-wire? The present straight-wire theory assumes that there is a certain fixed inclination of the labial or buccal surfaces of all teeth. The theory also assumes that the buccolingual or labiolingual steps are constant from tooth to tooth. Dellinger looked at fifty (twenty five non-extraction and twenty five extraction cases) wax set ups from a commercial positioner laboratory, from the parameters measured he found a totally inconsistent and erratic result had been achieved. The range of values was so great that he concluded "that it is possible that the present straight-wire theory has little scientific basis." He concludes in much the same vein as Balut et al. (1992) that with proper wire bending or conversely the proper lack of control an excellent result can be achieved.

Tooth contacts were not one of the referents included in Andrew's "six keys" which were largely responsible for the straight-wire system, so it is somewhat surprising that we expect it to deliver a functional occlusion. The mechanical models were not subjected to the action of specific functional patterns comparable to the aggregate of forces that shapes the anatomic parts and their relationships in an individual, and therefore should not be considered as functionally correct until tested.

ARTICULATOR AND SETTINGS.

The articulator used was a Sam 2, a semi-adjustable ARCON articulator. The settings borrowed from Weinberg (1963) in which he used a hypothetical patient to evaluate articulators and their performances. Zimmer, Jager and Mesenburg (1991) compared normal T.M.J. function in Class I, II, and III individuals. They showed differences in opening when studied axiographically (measures condyle translation not rotation) they stated however that these differences were of no clinical import. It was suggested mediotrusive and protrusive tracings were flatter in the Class III groups. Ingervall (1972) looked at the correlations between malocclusions and sagittal mandibular movements in children. He made the observation that Class II patients quite often had an enhanced rotational capacity. Mongini (1980) in his article points out that extensive remodelling of the temporomandibular joint takes place throughout adult life leading to marked changes. The degree of remodelling and the new shape imposed on the condyles are closely related to changes in the dentition. He states the remodelling could to a certain extent be considered as a functional adaptation of the joint to a new occlusal situation. (in some instances a distant precursor of symptoms of a pain-dysfunction syndrome) He concluded, as did Moss (1975) that occlusal conditions determined the course of condylar remodelling and that his findings cast doubt on the proposition that the gnathological determinants (particularly centric relation) are never changed in the course of time. Gianelly et al. (1988) tell us condylar position is unrelated to extraction treatment and bite depth, it had been postulated that the condylar position in patients treated in conjunction with four premolar extractions would be more posterior than those treated non-extraction. McLaughlin (1988) failed to find a definitive correlation between the type or severity of a malocclusion and temporomandibular dysfunction.

Statistics of condylar path variations according to Aull (1965) have no value for obtaining averages to be used in articulators as we treat a patient as we find him, and not as the average of many patients. Despite this we find most positioners used in orthodontic finishing are made on articulators using average values. Kunkemoeller (1992) states Great Lakes will use average values which they are not willing to release, they do however indicate they originate from Slavicek's work. Kesling (1992) indicates T.P. require only the hinge axis which they are happy to measure from the lateral cephalogram. Two orthodontists who value the use of fully adjustable articulators are Chiappone (1975) and Roth and Gordon (1981d) though the latter state if the appliance therapy brings the case close to occlusal requirements, "an average movement pattern that simulates the movement of a human mandible seems to be quite satisfactory." The settings on the Sam 2 articulator were as stated formulated by Weinberg (1963). From the literature reviewed perhaps it should be noted that for Class III malocclusions the functional protrusive Inclination of the mandible tends to be slightly flatter than those of Class I and Class II patients. For comparison the averages of Lundeen (1979) and Aull (1965) are also recorded.

	Weinberg (1963)	Lundeen (1982) (averages)	Aull (1965) (averages)
Condylar Incline	40°	45°	37°
Balancing Cusp Incline	40°	55°	50°
Bennett Angle	12°	7.5°	3°
Radius Condylar Path	3/4"	3/4"	3/8"
Intercondylar Distance	110mm	90-136(110)mm	111mm

CHAPTER 11: THE EXPERIMENT

The objectives of this experiment were to reduce as many of the variables associated with patients and study tooth contacts in centric relation before and after simulated orthodontic treatment. The fabrication of four hypothetical patients has been dealt with in the previous chapter as has the use of the articulator.

The actual wax malocclusions were produced by taking an impression of plaster models, these models had been chosen from cases available at the United Dental Hospital, Sydney. They were thought to be good examples of the four chosen malocclusions. The Formadent teeth were placed in the impression and wax was then poured to complete the model. Grossly malplaced teeth were re-set closer to the line of the arch. These models were then articulated and used to make the master moulds in silicon. Refer to Photograph 1, page 150

These four silicone moulds having been fabricated represented each Class of malocclusion. This enabled us to set the Formadent teeth in the mould in a reproducible malocclusion. The models were then completed by using Moyco Pink Beauty wax. The models had to be poured in increments to avoid problems with shrinkage, it was found early on that the wax tended to shrink by as much as 4%. On completion of the pour the models were hand finished to ensure the dimensions were correct before the fitting of the base plates. They were then remeasured to ensure the vertical dimensions were the same for each of the malocclusions. The individual models were then measured across the intercanine and intermolar widths to ensure they were as they should be. The final measurement was from the incisal pin to the lower molars once the models were mounted on the articulator.

The upper models were all mounted using the same facebow, this was to reduce the variables. It ensured the occlusal plane was the same for all cases and the distance from the joint to the incisors. The locating point was the indentations used to position the central incisors. Five models were set up in this manner:- two Class I malocclusions to enable us to treat one non - extraction and the second by extraction of the four first premolars. A Class II, div. 1 malocclusion which was treated with extraction of the upper first premolars and the lower second premolars. A Class II, div. 2, which was treated with the extraction of the upper first premolars only and finally a Class III malocclusion which was treated with the extraction of the lower first premolars and the upper second premolars.

Refer to Photograph 2, page 150

Measurements Relating to Lower Arch

	Inter-canine width (mm)	Inter-molar width (mm)	Lower incisor to incisal pin (mm)	Extractions	Change to lower incisor (mm)
Class I exo	27	43	28	4|4 / 4|4	-1
Class I non-exo	27	43	28	nil	nil
Class II,1	28	42	35	4|4 / 5|5	-0.5
Class II,2	29	47	31	4|4	nil
Class III	28	42	36	5|5 / 4|4	-3

The simulated orthodontic treatment was carried out much as one would carry out a typodont exercise. As stated tooth movement was to be within the envelope of discrepancy set out by Ackerman and Proffit (1985). The lower intercanine width and intermolar width was to be maintained and the anteroposterior movement of the lower incisors closely monitored to ensure they were moved to a predetermined realistic goal that could be achieved in the clinic. The upper arch was then treated to this position. In order to facilitate the anteroposterior correction and the camouflage of the skeletal malocclusion varying degrees of tip and torque were utilised in the anterior brackets. Class I, standard Roth prescription; Class II, Andrew's low torque prescription; and for the Class III the upper anterior brackets were Hilger's high torque and the lower anterior brackets were the Mini-Wick brackets. the torque and tip as shown in the table below:-

Table B: Pre-adjusted Brackets (degrees)

	Class I		Class II		Class III	
MAXILLARY	Torque	Tip	Torque	Tip	Torque	Tip
1	+14	+5	+7	+5	+22	+5
2	+7	+8	+3	+8	+14	+8
3	0	0	+7	+10	+7	+7
MANDIBULAR						
1	-1	0	-1	0	-5	0
2	-1	0	-1	0	-5	0
3	-11	+6	-11	+6	-7	+6

The treatment objectives were to align the teeth in the arches and produce a Class I molar and canine relationship, the exception being the Class II, div. 2 malocclusion where extractions were only carried out in the upper arch. This meant a Class II molar relationship would eventuate and a Class I canine relationship. Essentially Andrew's six keys were to be achieved and as optimum an occlusion as possible achieved. The treatment sequence was as follows. Where extractions were required, the teeth were removed and the wax re-modelled. Initial alignment was achieved with Wilcock 014 special plus wires, the canines were laced back to the molars in the manner described by Bennet and McLaughlin (1991). Once these wires had expressed themselves, the wire sequence used was as follows: Wilcock 016 special plus, 16X16 yellow Elgiloy, 16X22 yellow Elgiloy, 16X22 heat-treated yellow Elgiloy. The space closure was carried out using sliding mechanics after which the finishing wire 17X25 TMA was utilised. In each case the wires were amended to the arch form best suited to each malocclusion. The articulator and models were placed in a water-bath at 55°C to allow tooth movement to take place. As can readily be imagined, the process was time consuming as any failure in a bracket meant that the wire sequencing would invariably have to regress until alignment was achieved once more.

Once the simulated treatment had been carried out the models were examined to see the effect of extractions and dental compensations on the occlusal contacts that were obtained.

The occlusal records were made using GHM. occlusal foil. The foil is 20mm wide and 8u thick. Kelleher and Setchell (1984) indicate this is an accurate indicator of tooth contact. The foil was held in Miller's forceps for the recordings.

Refer to Photograph 4, page 152

The articulator was closed in a tapping action to record the contacts in centric occlusion. Following this the contacts were carefully mapped onto an occlusal diagram. The contacts were then tallied according to the number of teeth with inter occlusal contacts and the total number of contacts. This was repeated on ten occasions (five times on two different days) and the results tabulated. Should there have been a great variation between the two recordings a third recording would have been carried out after a period of two days. This was not necessary, the pilot experiment had suggested the readings would be reproducible. Ideally it would have been preferable to test ten different set ups for each malocclusion group, funds and time did not allow this to be the case.

Again on completion of the simulated orthodontic treatment the occlusal records were made in exactly the same manner as on the pretreatment models and tabulated. Photographs were also taken of a "typical" representative of one of the ten recordings made.

Refer to Photograph 5, page 153

The archwires were then removed and the teeth were allowed to "settle" this was done by reducing the incisal pin 1mm and immersing the models in the water bath at 55°c for ten minutes the upper and lower members of the articulator being held by an elastic band. The models were then chilled before the occlusal records were again recorded as before, on ten separate occasions in two sittings.

Refer to Photograph 3, page 151

The results were then tabulated to show group changes. The results were also statistically assessed to see if there were any significant relationships between the initial number of contacts as well as the end of treatment and after settling. The results were finally examined to see if conclusions could be reached regarding achieving the "ideal" or stylised tooth contact patterns so often seen in the text books of gnathology and occlusion. The tooth contacts were also checked in lateral and protrusive excursions for interferences and premature contacts.

Refer to Photograph 6, page 154

Analysis.

The results are presented in a range of tables. Each table has its limitations and extensive conclusions should be drawn from none. However, presented as they are a clinical picture can be formed as to the overall changes.

The number of occlusal contacts recorded at the initial pre treatment stage is recorded in Table 1 below.

PRE-TREATMENT (Mean Numbers)

	Class I	Class II,1	Class II,2	Class III
Total No of contacts	35	31	21	34
No of contacts on Ant teeth	9	7	1	11
No of contacts on Post teeth	26	24	20	23
Total No of teeth in contact	25	23	17	26
No of Ant teeth	9	7	1	10
No of Post teeth	16	16	16	16
Ideal contacts 1 tooth:1 tooth		56*	56*	56*
Ideal contacts 2 teeth:1 tooth	64*			64*

* according to Bauer and Gutowski, *Gnathology. Introduction to Theory and Practice.* Quintessence. Berlin 1976

The occlusal contacts have been counted in two main groups:-

1. The number of teeth in contact. Each tooth registered as one contact if it was in contact with an opposing tooth. There was no differentiation made according to the number of contacts a tooth made.

2. The number of cuspal contacts. With this method premolars were able to register two contacts if they had one or more on each cusp. Molars were able to register four or five contacts depending on their number of cusps.

These two groups were each subdivided into anterior (incisors and canines) and posterior teeth (premolars and molars).

The second table refers to the post simulated treatment contacts. The first group of figures A. refer to the end of appliance therapy and the second B. to the simulated "settling" of the teeth.

POST-TREATMENT (Mean Numbers)

		Class I non-exo	Class I	Class II,1	Class II,2	Class III	SEM
Total No of contacts	A	51	46	41	37	43	0.14
	B	53	46	42	38	42	0.13
No of contacts on Ant teeth	A	11	10	6	8	12	0.08
	B	12	10	8	8	10	0.00
No of contacts on Post teeth	A	40	36	35	29	31	0.13
	B	41	36	34	30	32	0.10
Total No of teeth in contact	A	27	22	18	20	24	0.10
	B	28	22	20	20	24	0.00
No of Ant teeth	A	11	10	6	8	12	0.00
	B	12	10	8	8	10	0.00
No of Post teeth	A	16	12	12	12	12	0.00
	B	16	12	12	12	12	0.10

The Student's *t* Test was carried out to determine the significance of the differences between the groups. The standard error of the mean is a pooled error from all classes. For some variables the variance for each group was zero and so no statistical comparison could be made, but in these cases if the means are different the differences between them are highly significant. Where the table relates to the number of posterior teeth in contact it is reasonable to find some groups are identical, there being identical brackets on the same number and type of tooth.

In the first comparison the pre treatment values were compared with the post treatment values. It comes as no surprise that there were highly significant differences between the two at the 0.01 probability level. Even when there were four premolars extracted the number of contacts increased. The use of the articulator having no neuromuscular pattern to give us best fit in the pretreatment cases.

In the two post treatment groups there were significant differences between the two groups. The settling produced was that described by Strang (1950) "inert things settle" and so one would expect the cusps to move towards the fossa. In real life as Razdolsky, Sadowsky and Begole (1988) tell us this is not always the case, living structures make readjustment and the cusp may not move, or in fact it may move away from the fossa. So although most clinicians believe that there is a period of "settling" or "readjustment" that improves the tooth contacts it is not always the case.

With the third table on the number of contacts per tooth the information contained within must be viewed with caution. :-

Average Number of Contacts Per Tooth

Tooth	Class I non-exo	Class I	Class II,1	Class II,2	Class III	SEM
Central Incisor	1	1	0.25	0.5	1	0.04
Lateral Incisor	1	0.5	0	0.5	1	0.04
Canine	1	1	1	1	1	0.03
Pre-Molars	1.75	2	2	1.66	1.75	0.03
First Permanent Molar	4	4	4	3.25	3	0.04
Second Permanent Molar	2.5	3	2.75	1.75	3	0.04

Essentially the table shows the mean value for each tooth, however it is a repeated measurement of the same set of models. The models were tapped together using articulator paper as described on ten separate occasions with the finishing wires in place and then another ten occasions after the simulated "settling" had occurred. As stated previously it would be far more meaningful to have ten measurements of different malocclusions that have undergone simulated orthodontic treatment. Despite all the care taken if there has been an error in the production of that occlusal form it will be repeated for each measurement. The variability in bracket placement has been discussed in Chapter 9 and although the bracket placement was done by the author under ideal conditions, utilising "normal teeth and checked by an experienced straight-wire operator (MS) there must be some variation.

The points of interest are the first molars produce the most contacts, even in the pre treatment assessment irrespective of their position/malposition they are worth at least one contact. The Class II molar relationship gave the least contacts in post treatment results (with the post treatment Class III malocclusion which has a Class I molar relationship) and this is not surprising in view of Bader's comments (1991) that the straight-wire concept revolves about a Class I molar relationship. Should this be altered he suggests one would have to accommodate for the changed relationship by increasing the rotation and tip of the upper first molar. As to the reason behind the post treatment results of the Class III malocclusion I would suggest it is a matter of pure conjecture.

The results do not critically assess the quality of the tooth contacts. The photographs demonstrate that both the intra arch tooth stability - no spacing, and the inter arch tooth stability - tooth contacts increased greatly. There were bilateral synchronous jaw contacts in centric occlusion. Interestingly enough in every case canine guidance resulted from lateral lower arch movement and anterior guidance from the anteriors with protrusion of the lower arch. The essentials of a good functional occlusion were provided.

Isaacson (1976) provides us with a good goal, "concisely stated a physiologic occlusion is one that is functioning in health. It should both satisfy the patient aesthetically and enable them to chew effectively and comfortably. Such an occlusion may have malposed teeth, it may have an intercuspal contact position that does not coincide with a retruded contact position. Such an occlusion may show evidence of wear. The individual may even be a bruxer. The significant feature is that the occlusion should have demonstrated its ability to survive."

With the therapeutic occlusion McCollum (1941), Ottolengui (1930) and Lucia (1979) to a lesser extent believe that there is one ideal occlusal design for each person based upon that individual's measurements as recorded by means of the gnathological tracing device. Practising orthodontists have for many years produced occlusions through arbitrary decisions and the patients have survived very well, the result being in their envelope of accommodation, The result has been physiological, as Isaacson (1976) states "I believe it is presumptuous to attempt to state nature's intent for ideal occlusion . . . I recommend the most accurate methods of measuring jaw movements, but feel that how an individual functions (or rather Parafunctions) and extent of pathology be considered as well."

As a conclusion I believe there is a strong relationship between occlusal stability, mandibular function and TMJ. health and that the practising orthodontist must be aware that as he changes the occlusion so too must the other factors involved compensate. Ideal tooth contacts are not a realistic goal for routine orthodontics, yet we must ensure we establish a good anatomic occlusion which does least to disrupt the balance of the stomatognathic system. To do this we must be aware there are more things to treating the malocclusion than the six keys of Andrew's and admiring hand held casts. The true test will be in function and perhaps a greater awareness of tooth contacts that occur in both centric and border positions of the mandible will allow us to provide a better long-term result for the patient.

The present study indicates that comparing one class with another adds little to the definition of "acceptable" occlusion. Mean value reasoning is not a good indicator for the individual. It must also be stated that occlusal interferences need not be present in post-orthodontic cases. Yet in order to produce "ideal" contacts occlusal equilibration will be required. Variables in tooth size and shape alone being sufficient to prevent an ideal result. The fourth dimension, time, is of the utmost importance as function will dictate a stable result. As has been stated before, one can move the teeth to where one thinks they belong but nature will place them where they best adapt to the needs of the rest of the stomatognathic system.

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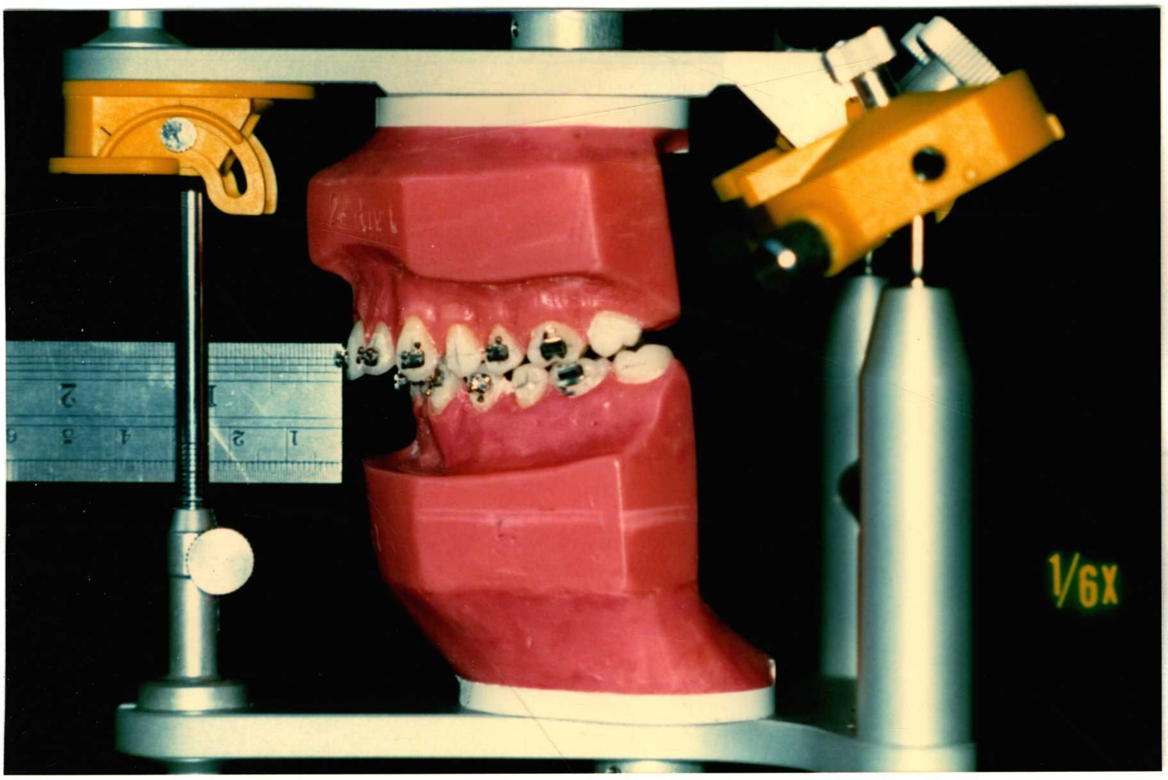
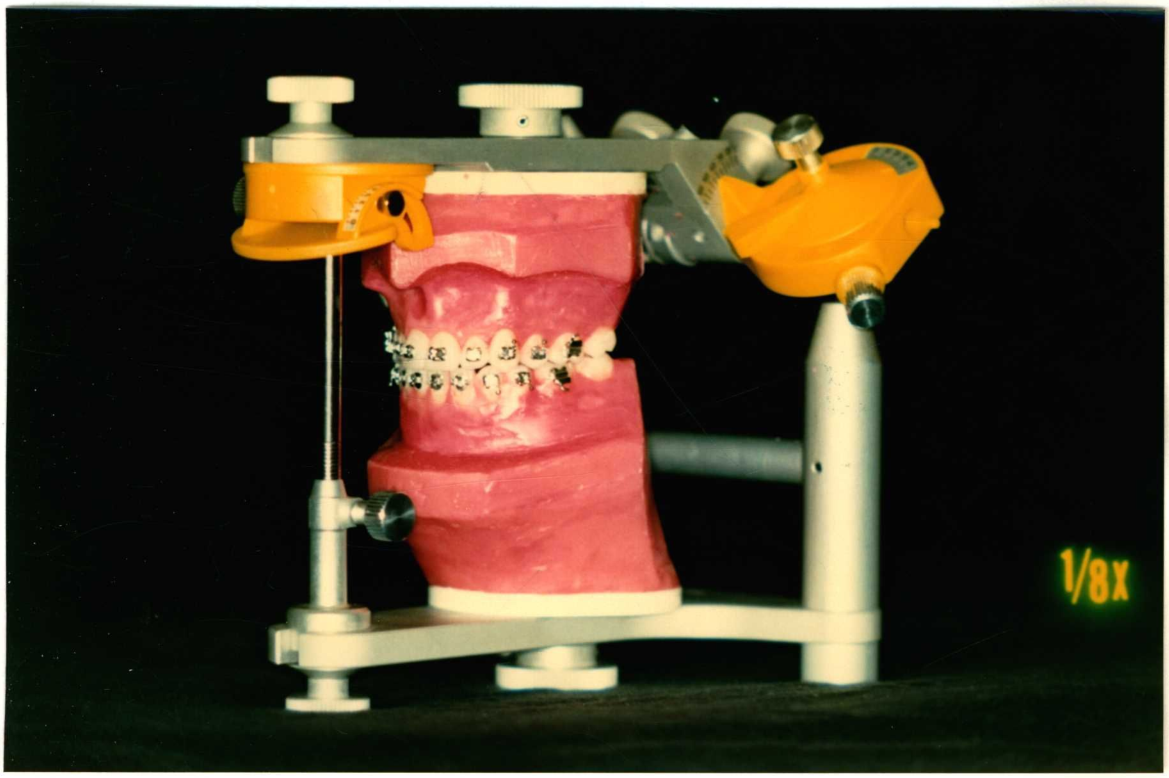
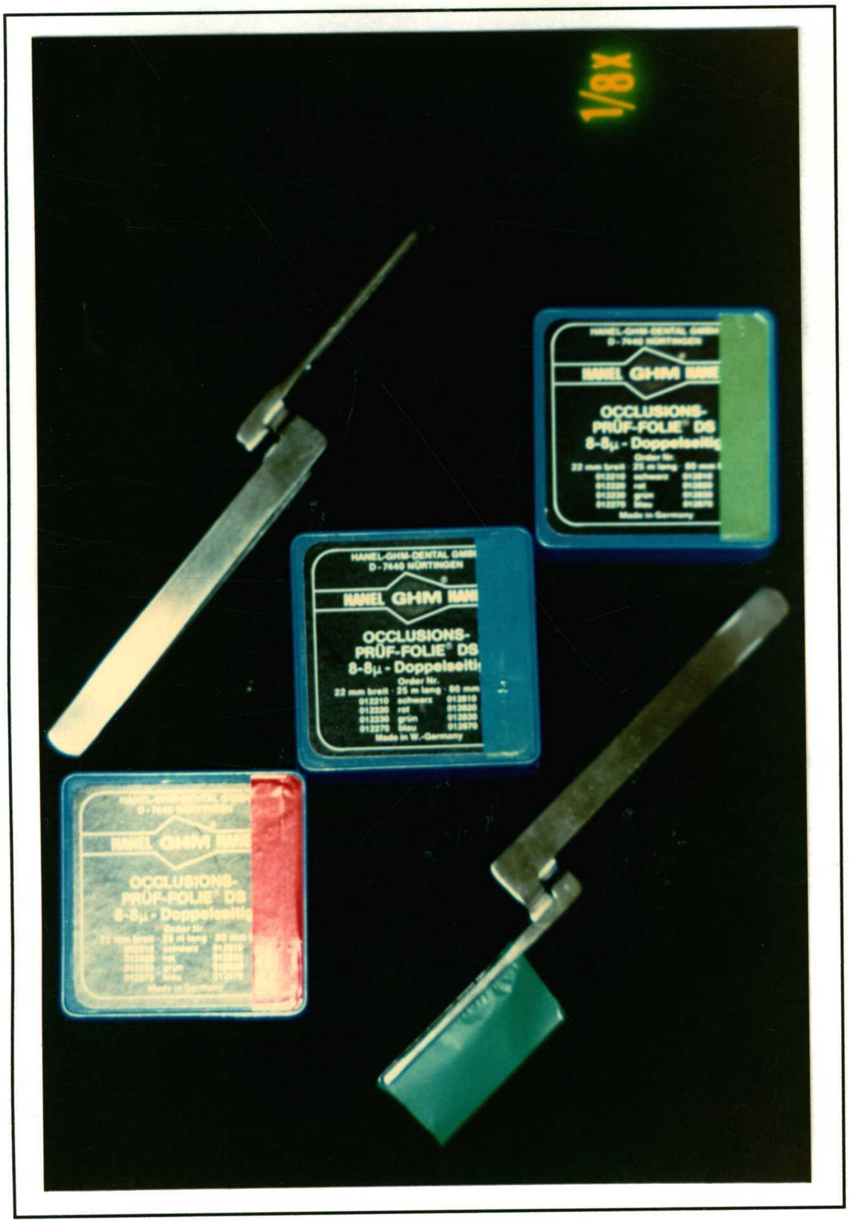
1. Class II, Div 1 Malocclusion Set-up



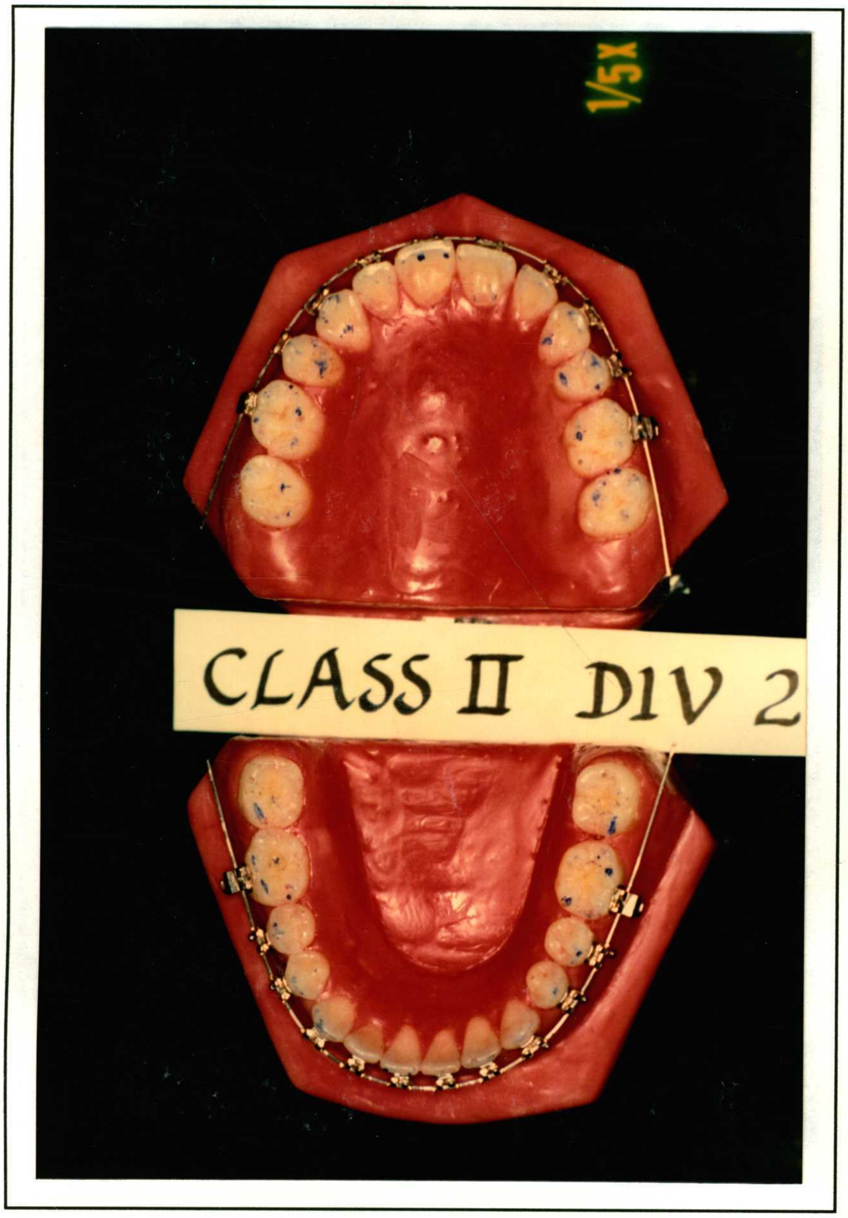
2 Class II, Div 2 Before Extractions



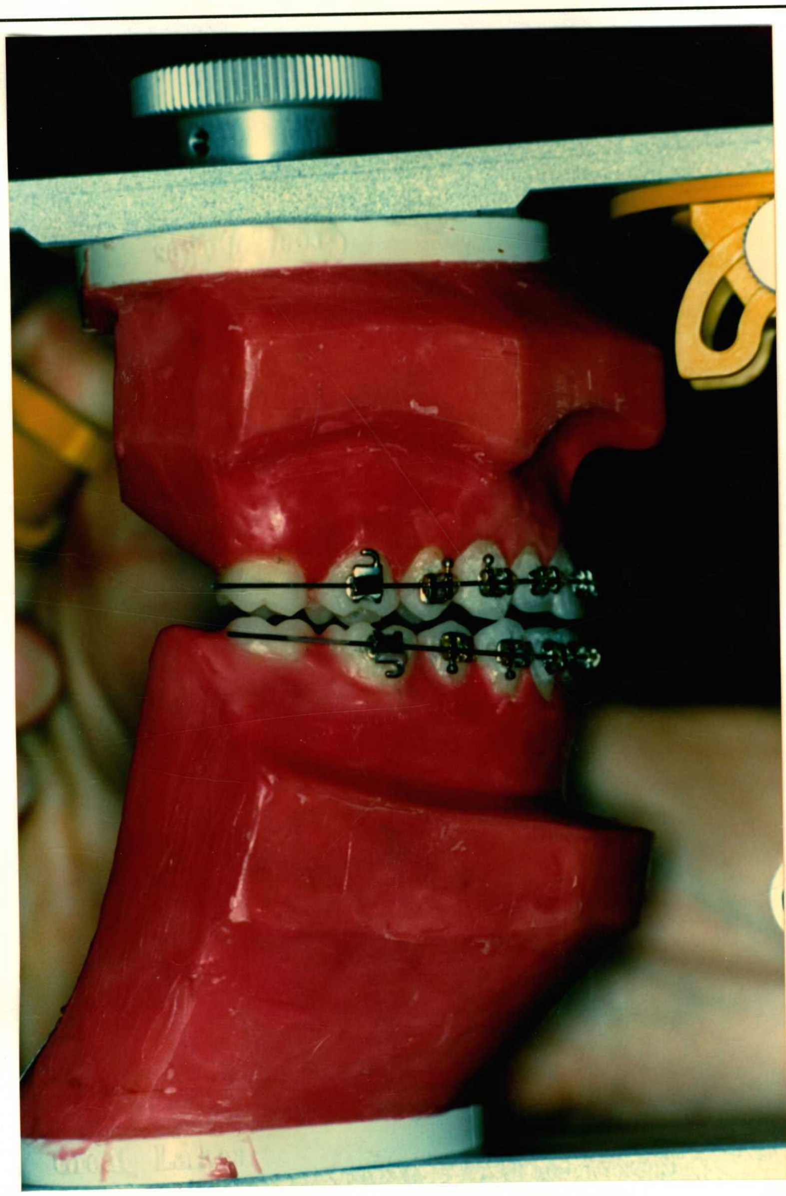
3. Settling with Archwires Removed



4 Miller's Forceps and GHM Foil



5 Tooth Contacts After Simulated Treatment



6. Canine Guidance in Lateral Excursion