# CRANIOFACIAL AND OCCLUSAL CHARACTERISTICS OF CHILDREN WITH PERSISTENT DIGIT SUCKING HABITS

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## ABSTRACT

The present study investigated persistent digit sucking habits among referrals to a Hospital Orthodontic Department. In particular, the prevalence of habits and their effect on dentofacial morphology, dental occlusion and orthodontic treatment need were investigated.

Over an eight month period 54 cases, or 6.1% of all new patients, were referred with persistent digit sucking habits. Two thirds were female, and the age range was 5 to 16 years. A Study Group of 44 cases over the age of 10 years was identified and compared with a Control Group of non digit sucking referred patients, matched for age and sex.

A commercially available computerised cephalometric analysis system was used to measure 19 linear and angular variables from standardised cephalometric lateral skull radiographs. A further 9 variables were determined from orthodontic study models of the two groups. Method error for all techniques was found to be within acceptable limits. Computerised analysis of results was undertaken, following conventional statistical methods.

The cephalometric data revealed digit sucking to be associated with a significant increase in maxillary prognathism, relative prognathism, maxillary incisor proclination and maxillary anteroposterior length, and to be associated with a significant reduction in interincisal

angle and angulation of the maxillary plane to the cranial base. No significant differences were observed for mandibular incisor proclination, face height, maxillary mandibular plane angulation, mandibular length or cranial base characteristics. Study model measurement revealed digit sucking to be associated with significantly increased prevalence of anterior open bite, increased overjet and reduced maxillary intercanine width. Maxillary intermolar width, together with mandibular intermolar and intercanine width were not significantly different. An increased prevalence of buccal crossbite among digit suckers failed to achieve significance. Presenting intensity of habits measured by reported hours digit sucking daily was found to be weakly associated with the observed characteristics, but may provide a useful index of priority for aversion therapy.

Orthodontic treatment need measured by an accepted index was found to be similar for both groups. The possibility remains that digit sucking was responsible for increasing the treatment need to a threshold level for referral, and that without the habits these patients would not have required referral to a specialist service.

It was concluded that persistent digit sucking is an important aetiological factor for malocclusion in patients referred to a Hospital Orthodontic Department, exerting an influence in anteroposterior, vertical and transverse dimensions. Although some minor skeletal changes were detected, the changes were principally dentoalveolar.

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## DECLARATION

This thesis is the original work of the Author, excepting such assistance and guidance as has been acknowledged.

**Matthew Baxter Moore.**

# CHAPTER 1

## INTRODUCTION

Orthodontics is unusual among Dental and Medical Specialities in that the problems being treated are generally considered to be in the realms of "natural variation", rather than resulting from a specific disease process. Many factors are regarded as having an influence on the natural variation in dentofacial morphology, and often these are grouped as being either "genetic" or "environmental". Presently, ethical considerations and limitations in scientific possibilities prevent any meaningful intervention on genetic control of dentofacial morphology. The situation is rather different for the environmental factors. Indeed a full understanding of environmental influences on dentofacial morphology and occlusion opens up possibilities of creating conditions which are favourable for optimum dentofacial growth, and removing those conditions found to have an unfavourable influence.

Oral habits are probably the most easily recognisable environmental factors which could influence dentofacial development, and for many years there has been considerable interest and controversy among the Orthodontic Profession about the role of oral habits in the pathogenesis of malocclusion. In particular, digit sucking habits have been of special interest to orthodontists. Anecdotal evidence and opinion are gradually giving way to hard scientific evidence as modern research methods are applied to an age old problem.

Chapter 2 provides a detailed review of the literature relating to digit sucking habits. The greatest majority of research on the topic has emanated from Scandinavia and North America and relates to the problem in these geographical regions. By comparison, much less has been published about the problem as it relates to Great Britain, with it's different culture, attitudes and genetic pool. Clinical experience suggests that patients with digit sucking habits form a substantial proportion of the workload of Hospital Orthodontic Departments, with consequent impact on health service resources, although to date no figures have been published on the magnitude of the problem as it affects a British Hospital Orthodontic Department.

There would seem little doubt that digit sucking can influence dentofacial development and contribute to malocclusion. Identification of the nature and location of the influence is less certain, and the application of modern cephalometric techniques is likely to enhance current understanding of the role of digit sucking on the development of malocclusion. Furthermore, detailed analysis of a British sample would enable valuable comparison with published results for other races.

Anecdotally, digit sucking habits appear to exert a substantial influence on the need for orthodontic treatment and yet allow the potential for beneficial intervention. Better management of the problem will be based on a fuller, more detailed understanding of the role of digit sucking on the development of dentofacial morphology and the dental occlusion.

# CHAPTER 2

## LITERATURE REVIEW

### A. Introduction

The literature relating to the problem of digit sucking habits is extensive and covers many aspects of the behaviour and its consequences. Studies can be broadly grouped into those which investigate:-

(i) Definitions and classification of digit sucking.

(ii) Prevalence of such habits.

(iii) Aetiology

(iv) Physical sequelae.

(v) Treatment modalities and their success.

Each of these logical groupings will be considered in turn.

### B. Definition and classification of digit sucking habits.

In the present context the Concise Oxford English Dictionary defines a "habit" as "settled or regular tendency or practice" and "a practice that is hard to give up". Correspondingly a "digit" is defined as a finger (including the thumb) or toe. "Digit sucking habits" may therefore be defined as the regular practice of sucking a finger or thumb, a practice which may be difficult to give up.

There have been few attempts to classify digit sucking habits either generally or by the orthodontic profession, but Larsson and Dahlin (1985) have distinguished between "Initial Sucking Habits" and "Prolonged Sucking Habits". The Initial Sucking Habit was described as a "daily habit, evident in the small child after several months" and relates to the behaviour of the young infant. Figure 1 shows a photograph of a 5 month old infant with an initial digit sucking habit. In contrast Larsson (1985) described a Prolonged Sucking Habit as "one which prevails until at least 6-7 years of age". Figure 2 shows a photograph of a 10 year old child with a prolonged digit sucking habit.

Larsson's terminology remains the most useful descriptive classification of digit sucking habits, most especially because it relates to the age of the patient. Of particular importance is the cut-off age of 6-7 years, beyond which the habit is considered to be prolonged, for this is the age when eruption of the permanent dentition begins.

Figure 1

A 5 month old infant with an initial digit sucking habit.

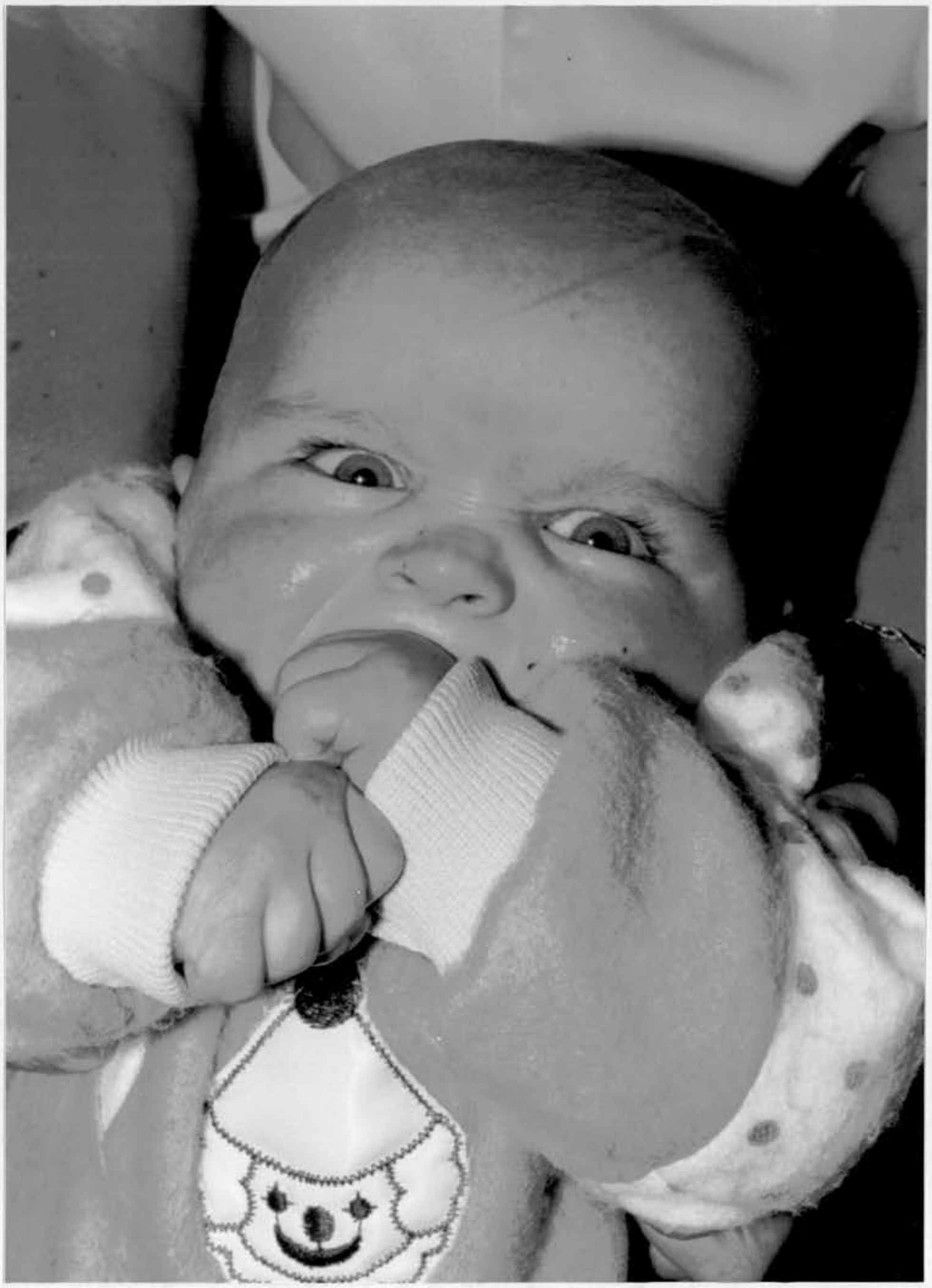
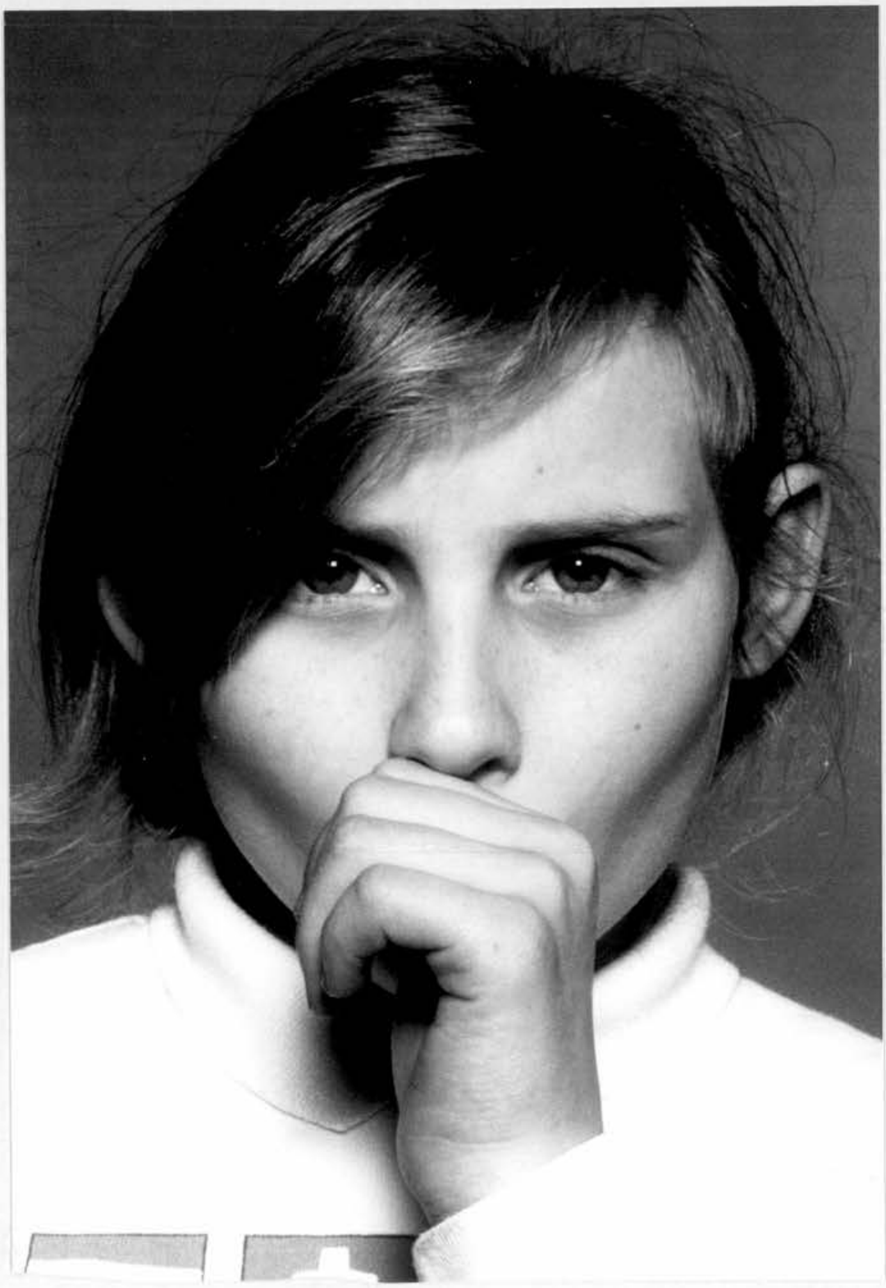


Figure 2

A 10 year old child with a prolonged digit sucking habit.



C. Prevalence of digit sucking habits.

The prevalence of digit sucking habits is not constant for all population groups and is dependent on such variables as age, sex and racial culture. Furthermore a number of studies would suggest that the prevalence of such habits is changing with time for given population groups. Digit sucking is an extremely common behavioural characteristic, and Nunn (1978) stated that in the 1970's 40 million American children were affected, about 45% of all children up to puberty.

When evaluating prevalence studies relating to digit sucking habits, care must be exercised for studies do not all evaluate prevalence of initial sucking habits in the same manner. Some studies do quote genuine point prevalence figures, obtained by determining what percentage of a sample actually have a digit sucking habit at the time of the investigation. An alternative technique is to make a retrospective enquiry by asking older children or their parents if they had a habit when they were younger. Such a method is likely to lead to underestimation of the age when the habit stopped, especially if it is the child who answers the questions, because of the implication in the enquiry about age that the habit may have been childish or immature. When estimating the change in prevalence figures with age, by far the most valuable design of study is the longitudinal study of a single group. However such a method is probably the most demanding for the researcher, and indeed there have been relatively few such studies published.

Traisman and Traisman (1958) reported a large survey of 2650 patients attending a paediatric clinic with respect to digit sucking. The group ranged in age from birth to 16 years old and were middle class Caucasians living in the USA. 1208 (45.6%) were found to have digit sucking habits. Three quarters of the habits were initiated in the first three months of life and the remaining quarter during the rest of the first year of life. The mean age for stopping habits was 3.8 years, although some were noted to continue until 12 to 15 years of age.

Gardiner (1956) surveyed 1000 Sheffield school children in the age range 6-15 years. 16% had some history of digit sucking prior to 5 years of age, and 11.2% had a history of digit sucking persisting after the age of 5.

Amongst 1258 children who had records taken in 1953 in Ontario Canada, Popovich and Thompson (1973) found an overall prevalence of 36.7% for digit sucking habits, decreasing from 40.0% for 6 year olds to 28.4% for 12 year olds. It is not clear from the paper, however, whether these figures are for children who were still sucking at the time of the enquiry, or whether the figures relate to a retrospective enquiry into previous habits. It seems likely that the latter situation is the case. Of those with sucking habits, 19.9% were finger suckers, 70.6% were thumb suckers and a further 9.5% were blanket suckers. Children who had used a dummy had significantly lower rates of digit sucking.

Bowden (1966) examined 58 boys and 58 girls as part of a multidiscipline growth study at the University of Melbourne. 38.8% were found to develop digit sucking habits, and the behaviour was found to be more prevalent among girls. 21 out of an original 45 children with the habit, were still sucking digits at 8 years old.

As part of an extensive survey of nutritional status of American children, Infante (1976) reported on the prevalence of digit sucking amongst 680 white and 141 black American children in the age group 2.5 - 6.0 years. 23.5% of 2 year olds had such a habit, declining to 14.6% by the age of 6 years old.

An investigation by Baalack and Frisk (1971) into finger sucking and malocclusion in some 8,158 12 year old Stockholm children revealed that 30.7% had at some time had a digit sucking habit. More than half (57%) had given up their habit by the time they went to school and by the age of 12 years old only 1.9% still had a habit. Digit sucking was shown to decrease in prevalence with increasing age. A similar trend was noted by Lundstrom (1959) who investigated 196 twins and reported that 21.4% gave a history of sucking prior to the age of 5, falling off to 12.2% after that age. In a study of American children Kelly et al (1973) reported that 45% of 3-4.5 year olds were digit suckers and this figure fell to 5.9% by the age of 11 years. Dutch children were found to have very high prevalences for digit sucking of 57% and 66% for boys and girls respectively at 5 years old, with figures of 29% and 38% at 9 years old.(de Boer 1972), again confirming that digit sucking habits decrease with age.

It will be noted that the prevalence figures already quoted are quite high, but there have been lower figures quoted in the literature. Gedda (1948), cited in Larsson (1971) gave a figure of only 1-2% amongst Gothenburg children. Such low prevalences do not, however, appear to be the norm for Western societies.

When all types of initial sucking habits are considered, prevalences as high as 95% are often reported, although dummy sucking usually accounts for the greatest proportion of cases. A number of studies into initial digit sucking habits have also focused on initial dummy sucking habits, which would appear to be closely related to habits involving digits.

At a symposium on Feeding and Dentofacial Development at Oslo University, Lindner (1990) presented the results of a study of 588 4 year old children from Huddinge, Sweden. It was found that 88% had some previous or persisting sucking habit with 78% of these involving a dummy. 48% still had a habit when they were examined at four years of age.

In a study directed specifically at dummy sucking habits, Svedmyr (1979) reported a prevalence of 16% for digit sucking amongst 462 consecutive attendances at a Swedish paedodontic practice. The age range was 1-11 years although more than 50% were under 5 years old. The habit was found to be significantly more common amongst girls. The study found that 62% of the children had a history of dummy sucking, and also observed that 3% of the sample had started as dummy suckers and then changed to digit sucking. No sex difference was observed in the prevalence of dummy sucking.

Of the 1000 Sheffield children investigated by Gardiner (1956) 195 had a history of some dummy sucking, but interestingly only 7 cases subsequently developed digit sucking habits when the dummy was withdrawn.

Kohler and Holst (1973) examined 1567 4 year old children in southern Sweden and found that 30.1% had a persisting digit sucking habit with a corresponding figure of 10.7% for dummy sucking. Bowden's 1966 study of 116 Melbourne children also showed that dummy sucking habits tend to be discontinued at an earlier age than digit sucking. All dummy suckers were found to have stopped their habit by the age of 2 $^{1}/_{2}$ years while almost 50% of digit suckers still had their habit at 8 years old.

Zadik et al (1977) investigated sucking habits amongst Israeli children between birth and 7 years old, living in three different communities, and reported a prevalence of between 13% and 58% for thumb sucking. Prevalence was highest in a Kibbutz where pacifiers were withheld. When all forms of initial sucking habit were considered, up to 95% of children were found to have a habit. Golden (1978) also investigated children living in an Israeli Kibbutz and reported that digit sucking habits were more prevalent and more persistent than in a number of other studies. 56% of children in the age range 7-12 years old gave a history of having had a digit sucking habit at some time.

Some differences have been observed in the pattern of dummy sucking habits compared to digit sucking habits. Ravn (1974) investigated sucking habits among Copenhagen children up to the age of three years, and reported that while dummy suckers showed a sharp reduction in number with age ( 84.3% at 1 year falling to 47.1% at 3 years), finger suckers appeared to be much more persistent with 17 out of an original 20 children still sucking at three years.

A similar observation was made by Modeer et al (1982) who examined 588 Swedish children with a mean age of 48 months and recorded prevalence of initial sucking habits. 515 children (88%) had initial sucking habits, 78% of which involved a dummy and 18% of which involved a digit. Parental interviews revealed that while dummy sucking prevalence peaked at approximately 1 year old and then declined substantially over the next 3 years, digit sucking prevalence remained quite constant throughout the same period.

Melsen et al (1979) reported that out of 723 Danish children in the age range 10-11 years, 78% had previous dummy sucking habits, 8% had history of digit sucking habits and only 14% had never had a sucking habit. These figures were interpreted by the author as indicating that Danish children use pacifiers more commonly than some other races, and supported the suggestion by Larsson (1978) that such habits were increasing at that time in Scandinavia.

At the symposium on Feeding and Dentofacial Development held at Oslo University in 1990 a number of researchers presented data on prevalence of sucking habits. Ogaard and Lindsten investigated 3 year old children in Sweden and Norway, and looked at 171 from Falkoping (Sweden) and 163 from 3 towns in Norway. Prevalence of sucking habits in Falkoping were 70% for dummy sucking, 18% for digit sucking and 12% with no habit. Prevalence of dummy sucking in the Norwegian towns ranged from 39% to 57%, while digit sucking from 10% to 18%. No sucking habits were observed in 25% to 49% of the Norwegian samples. These figures support the finding of Ogaard (1989) that Norwegian children had a lower prevalence of sucking habits than did children from Sweden and Denmark. Furthermore it was reported that nearly all children who had developed digit sucking habits were still sucking at three years of age.

Kristensen (1990) presented the results of a longitudinal study of 213 children in Nyborg, Denmark, from birth to five years. In the first year, 92% had some form of sucking habit. At five years dummies were the commonest type of sucking habit, but in those who did not use a pacifier, digit sucking habits were found to be much more common. When prevalence of habits relative to age was considered, digit sucking remained more constant then other habits and the digit sucking group was found to be dominated by females and children from the middle socio-economic classes.

Larsson (1975) investigated 3349 Swedish 4 year olds, and found that 22% had a history of an initial digit sucking habit, only falling to 18% by the age of 4 years. Dummy sucking was much more prevalent initially at 55%, but had fallen very substantially to 20% by the age of 4 years.

Ogaard (1989) investigated 60 five year old Norwegian children and reported a prevalence of 30% who were or had been digit suckers, with a corresponding figure of 37% for dummy sucking. While most dummy suckers had broken their habits by the age of 3 or 4, many digit sucking habits were still active at 5 years old.

Holm and Arvidsson (1974) included oral habits in a general investigation into oral health amongst three year old children in Sweden. 208 children were investigated and 16% still had a digit sucking habit at three years old. The corresponding figure for dummy sucking was 87%.

Larsson (1987) gave consideration to trends in sucking habits with time for the same race. Larsson reported that the prevalence of initial digit sucking habits has decreased substantially in Sweden during the last few decades, citing figures of 50% in the forties (Klackenberg,1949), 30% in the sixties (Larsson, 1971) and about 15% in the eighties. Larsson also suggested that this reduction in initial digit sucking habits has resulted in a reduction in prolonged sucking habits.

The observation of changing prevalences of sucking habits with time was further supported by two studies carried out by Larsson. In 1971 he investigated 920 nine year old Swedish children and enquired about previous and persisting thumb and dummy sucking. Initial digit sucking prevalence of 30% was reported, and this was found to decline steadily to 12% at 9 years old. Dummy sucking prevalence was much higher initially at 45% but this declined more rapidly to almost zero by 7 years old. In a subsequent follow-up investigation of 9 year olds some 14 years later, Larsson (1985) reported an increase in the percentage of children developing an initial dummy or finger sucking habit from 68% in 1971 to 90% in 1985, and attributed this to a marked increase in the number of dummy suckers. Conversely initial digit sucking habits were seen to fall from 30% in 1971 to 16% in 1985, and during the same period the percentage of children with a prolonged digit sucking habit had decreased from 14% to just 6%. In addition to demonstrating an increase in initial sucking habits in Sweden during the sixties and seventies, this study also demonstrated that children who did develop habits took longer to break them.

These trends would appear to be continuing and Nowak (1991) reported that at two International Symposia, held in Brussels in 1986 and Chicago in 1988, researchers concluded that non-nutritive sucking habits in children in industrialised countries were increasing. A further symposium in 1990 at Oslo also concluded that sucking habits are increasing in industrialised countries.

The previously mentioned studies have concentrated mainly on Westernised populations but a number of studies have investigated prevalence of digit sucking habits in non Westernised cultures. In a study of 580 Tanzanian children (mean age 6.1 years ) compared with 575 Finnish children (mean age 4.6 years ) Kerosuo (1990) reported that African and Asian children had prevalences of habits of 10% and 4% respectively while the corresponding figure for Finnish children was 10%. Furthermore the prevalence of anterior open bite in both countries was found to be significantly higher for the finger suckers compared to non finger suckers. Massler (1963) also reported no finger or dummy sucking in African tribes, while Moss and Picton (1968) found a very low prevalence of 1.8% amongst children under the age of 12 on the Greek island of Euboea.

Digit sucking habits were found to be non-existent among over 1000 Eskimo children living in the Canadian Arctic Circle (Curzon 1974) and the author attributed this to the lack of any opportunity to learn such habits as a result of the feeding pattern.

Larsson and Dahlin (1985) investigated digit sucking habits amongst three very different groups of infant material. 415 children under the age of 5 years from Mberengwa, Zimbabwe had a low prevalence of digit sucking habits at just 2%. A sample of 20 skulls from the collections of the Anatomical Institute of Oslo University, dating from the period 1000-1500 AD, demonstrated a similarly low prevalence of digit sucking habits (5%) as diagnosed from occlusal abnormality. However a significantly higher prevalence of 15% was seen amongst 280 Swedish children aged between 2 and 18 months old. Furthermore, the Swedish children also had a high prevalence of dummy sucking (72%) which was not seen in either of the other two groups.

Larsson (1983a) described a more extensive study of 81 medieval skulls from the Anatomical Institute of Oslo University, which were in the deciduous or mixed dentition stages of occlusal development. Only two of the skulls demonstrated malocclusions which the author interpreted as being related to digit sucking. The author used this evidence to support the theory that modern industrialised society contains factors which are conducive to the development of digit sucking habits.

Jenkins et al (1984), together with Calisti et al (1960) have both reported that digit sucking habits are less prevalent amongst the lower socio-economic classes although this may be an indication that lower socio-economic groups present themselves for assessment less readily than the higher socio-economic groups. Kohler and Holst (1973) reported that sucking habits are related to socio-economic status, with digit sucking being more prevalent in higher groups and dummy sucking more prevalent in lower groups, both trends being highly statistically significant.

Many of the studies of the prevalence of digit sucking habits have investigated the relative prevalences for girls and boys. Traisman and Traisman (1958), together with Holm and Arvidsson (1974) and Zadik et al (1977) could find no significant difference in prevalence between the sexes. However these papers appear to be in the minority, since many authors have reported that digit sucking habits are more common amongst girls than boys.

Graber (1958), Honzik and McKee (1962), Bowden (1966), Baalack and Frisk (1971), Larsson (1971), de Boer (1972), Kelly et al (1973), Popovich and Thomson (1973), Ravn (1974), Larsson (1975), Infante (1976), Svedmyr (1979), Larsson (1985), Kerosuo (1990) and Kristensen (1990) all agreed that the problem was more prevalent in girls compared to boys. The difference observed by Baalack and Frisk was so great that they pointed out that prevalence for girls was twice that for boys. Ravn (1974) found that boys tended to give up their habits at an earlier age than girls. Honzik and McKee investigated the difference in some depth, and found that it was not possible to demonstrate a measurable difference between the sexes until after the first birthday, at which time digit sucking became more prevalent in girls.

It has been postulated that Psyche may also influence prevalence of oral habits, and in 1968 Gershater reported that 24.5% of "emotionally disturbed" children had sucking habits compared to a figure of 17% for the general population.

The results of the various studies of prevalence of sucking habits reviewed are summarised in Table 1.

Table 1(i)

Summary of studies of prevalence of digit sucking habits.

| Author (Year) | Location | Age of children Examined | Number | Prevalence | Sex Difference | Type of Study |
|---|---|---|---|---|---|---|
| Gardner (1956) | U.K | 6-15y | 1000 | 16% before 5y<br>11.2% after 5y | Not Stated | Retrospective. Enquiry. |
| Traisman and Traisman (1958) | U.S.A | 0-16y | 1208 | 45.6% | No sex difference | Point Prevalence |
| Lundstrom (1959) | Sweden | 1-14y | 196 | 21.4% before 5y<br>12.2% after 5y | Not Stated | Retrospective Enquiry. |
| Backlund (1963) | Sweden | 8y | 280 | 6% | Not Stated | Point Prevalence. |
| Bowden (1966) | Australia | 0-8y | 116 | 38.8% initially<br>18.1% by 8y | F>M | Longitudinal Study. |
| Moss and Picton (1968) | Greece | 0-12y | 553 | 1.8% | Not Stated | Point Prevalence. |

Table 1(ii)

Summary of studies of prevalence of digit sucking habits.(continued)

| Author (Year) | Location | Age of children Examined | Number | Prevalence | Sex Difference | Type of Study |
|---|---|---|---|---|---|---|
| Baalack and Frisk (1971) | Sweden | 12y | 8158 | 30.7% "initial"<br>1.9% at 12y | F>M | Retrospective Enquiry. |
| Larsson (1971) | Sweden | 9y | 920 | 30% "initial"<br>12% at 9y | F>M | Point prev. at 9years, retrospective before then. |
| de Boer (1972) | Netherlands | 5-10y | 442 | 57-66% at 5y<br>29-38% at 9y | F>M | Longitudinal Study. |
| Kelly et al (1973) | U.S.A | 3-11y | | 45% at 3-4y<br>5.9% at 11y | F>M | Point Prevalence. |
| Kohler and Holst (1973) | Sweden | 4y | 1567 | 30.1% | Not Stated | Point Prevalence. |

Table 1(iii)

Summary of studies of prevalence of digit sucking habits.(continued)

| Author (Year) | Location | Age of children Examined | Number | Prevalence | Sex Difference | Type of Study |
|---|---|---|---|---|---|---|
| Popovich and Thomson (1973) | Canada | 3-12y | 1258 | 36.7% | F>M | Longitudinal Study. |
| Curzon (1974) | Canadian Eskimos | "Children" | 1000 | Nil | N/A | Point Prevalence. |
| Holm and Arvidsson (1974) | Sweden | 3y | 208 | 16% | "No marked difference" | Point Prevalence. |
| Ravn (1974) | Denmark | 3y | 248 | 8.1% before 3y<br>6.8% at 3y | Boys cease habit earlier. | Point prev. at 3 years, and retrospective prior to that. |
| Larsson (1975) | Sweden | 4y | 3349 | 22% "initial digit habits"<br>18% at 4y | F>M | Point prev. at 4 years, and retrospective prior to that. |
| Infante (1976) | U.S.A | 2.5-6y | 821 | 23.5% at 2y<br>14.6% at 6y | F>M | Point Prevalence. |

Table 1(iv)

Summary of studies of prevalence of digit sucking habits.(continued)

| Author (Year) | Location | Age of children Examined | Number | Prevalence | Sex Difference | Type of Study |
|---|---|---|---|---|---|---|
| Zadik et al (1977) | Israel | 0-7y | 333 | 13-58% (diff. Kibbutz) | No sex difference | Point Prevalence. |
| Melsen et al (1979) | Denmark | 10-11y | 723 | 8% | Not Stated | Retrospective Enquiry. |
| Svedmyr (1979) | Sweden | 1-11y | 462 | 16% | F>M | Point Prevalence |
| Modeer et al (1982) | Sweden | 4y | 588 | 18% | Not Stated | Retrospective Enquiry. |
| Larsson (1983) | Medieval Swedish skulls. | Deciduous or mixed dentition. | 81 | 2.5% | Not Stated. | Diagnosis from occlusal features. |

Table 1(v)

Summary of studies of prevalence of digit sucking habits.(continued)

| Author (Year) | Location | Age of children Examined | Number | Prevalence | Sex Difference | Type of Study |
|---|---|---|---|---|---|---|
| Larsson (1985) | Sweden | 9y | 273 | 16% "initial" 6% at 9y | F>M | Point prev. at 9 years and retrospective prior to that. |
| Larsson and Dahlin (1985) | Zimbabwe<br>Sweden | <5y<br>2-18 months | 415<br>280 | 2%<br>15% | Not Stated | Point Prevalence. |
| Ogaard (1989) | Norway | 5y | 60 | 30% | Not Stated | Retrospective Enquiry. |
| Kerosuo (1990) | Tanzania | 6.1y | 580 | ( African 10% ( Asian 4% | | Point Prevalence. |
| | Finland | 4.6y | 575 | Finnish 10% | F>M | |
| Ogaard and Lindsten (1990) | Sweden<br>Norway | 3y<br>3y | 171<br>163 | 18%<br>10-18%(diff. towns) | Not Stated | Point Prevalence. |
| Lindner (1990) | Sweden | 4y | 588 | 88%(all types of initial habit) | Not Stated | Retrospective Enquiry |

In summary it is possible to make the following comments regarding the prevalence of digit sucking habits:

1. The number of children in Western society who have at some time had a digit sucking habit is in the region of 25-35%
2. When all initial sucking habits are considered together (i.e. dummy sucking and digit sucking ) the prevalence in the Western world is in the range 75% to 95%.
3. Prevalence of digit sucking habits decreases with age.
4. Prevalence figures for prolonged digit sucking habits vary, but may be in the range 6-12% at 5-10 years old.
5. Among certain non-Westernised cultures digit sucking is extremely uncommon.
6. A trend towards decreasing prevalence of digit sucking over recent decades has been observed in Western cultures.
7. Conversely, prevalence of dummy sucking appears to be increasing in Western cultures.
8. A large majority of studies agree that the problem of digit sucking is more common in girls than in boys. Up to the age of 1 year, however, levels appear to be similar for both sexes.
9. It is likely that in societies where dummies are readily available, that prevalence of digit sucking

habits is lower than in societies which are similar in all respects other than the availability of dummies.

10. Children with dummy sucking habits give up their habits at a much younger age than do digit suckers.

C. Aetiological factors in digit sucking habits.

Living in a modern Western country, it is easy to consider that it is entirely normal for infants to suck their thumbs or fingers. However the studies of children from different races and populations would suggest that there are factors present in the modern Western life-style which are responsible, in some part at least, for the initiation of digit sucking, for if the habit were simply an innate behavioural characteristic for human beings, one would expect to see the behaviour in all races and in groups of the same race at different periods in time.

Most children with sucking habits develop them in the first year of life or shortly before weaning (Schneider and Peterson 1982). Traisman and Traisman (1958) found that 75% of infants who sucked their thumbs began to do so in the first three months of life, and the remaining 25% did so in the rest of the first year of life . Only a relatively small number will become prolonged digit suckers as defined by Larsson (1985). It is therefore pertinent to consider aetiological factors for the initial habit, and also aetiological factors for the continuation of the habit beyond infancy.

In considering the topic of aetiology it is important to emphasise that there has been and still exists some controversy as to whether digit sucking is a simple learned behaviour pattern or a symptom of emotional disturbance.

The learning theory suggests that the initial sucking habit develops as a way of dealing with an unmet natural sucking urge, and that the prolonged habit is simply a learned behaviour. The alternative approach, attributing digit sucking to emotional disturbance has a more Freudian psychological basis. According to Freud, children must go through certain phases of emotional development, such as oral, anal and genital phases. A requirement for successful emotional development is that each phase must be completed and discontinued before the next phase begins. Freud considered the sucking urge to be part of the oral phase, and if a sucking habit persisted into the next phase of development then a "fixation" of the habit would arise. Furthermore, if a child broke a sucking habit at the end of the oral phase,and then as a result of some form of emotional stress, restarted the sucking habit some years later then this would be considered to be "regression". Both regression and fixation are considered by Freud to be symptoms of emotional disturbance.

Current opinion would seem to favour the behaviourists' approach although it is likely that some psychological influences are implicated in the development of the initial sucking habit.

Larsson and Dahlin (1985) have suggested that the infant has a natural sucking urge or drive as a means of achieving adequate nutritional sustenance. If feeding mechanisms are very efficient, such as the case with bottle feeding, the child may fulfil its nutritional requirements while still having some surplus sucking urge. Non-nutritive sucking on a digit, a dummy or the mothers breast may then occur in an attempt to satisfy this surplus sucking urge. The authors use this theory to explain the difference in prevalence rates for digit sucking between the well nourished Swedish children in their study who spent relatively little time sucking for food and the less well nourished African children who spent much longer sucking at the breast for milk.

Jacobson (1979) also believed that sucking habits arise from an unmet sucking need, and suggested that a child's sucking need may range from 2 hours to just a few minutes. Such a variation would account for the fact that not all children develop habits despite experiencing similar feeding patterns.

While the theory of initial sucking habits being initiated due to an unmet sucking urge has a psychological component, Anke (1972a) found no evidence to substantiate the concept that prolonged sucking habits result from emotional disturbances. Curzon (1974) pointed out that non-nutritive sucking is now considered to be simple learned behaviour.

This approach to the behaviour pattern would appear to be a widely accepted philosophy and has largely displaced the beliefs of authors like Kaplan (1950), Klein (1971), and Peterson (1968) who believed that prolonged thumb sucking was a symptom of emotional disturbance for which the treatment should be based on the aetiology. Davidson et al (1967) argued that the psychoanalytical theories of digit sucking were largely based on personal opinion, and not on experimental evidence. The authors strongly supported the learned behaviour approach, and used as evidence the fact that in their study stopping thumb sucking habits did not lead to a substantial rise in alternative habits.

There has for some time been controversy over the role of feeding methods in initiating digit sucking habits. Meyers and Hertzberg (1988) investigated the role of bottle-feeding in malocclusion and were unable to find an association between mode of infant feeding (i.e. breast or bottle) and non-nutritive sucking habits with either digits or dummies. This supported the finding of Traisman and Traisman (1958) that breast feeding was not a significant factor for the incidence of finger sucking.

Hanna (1967) concluded that feeding by bottle, breast and bottle or breast alone makes little difference in regard to the development of oral habits. Klackenberg (1949), Ravn (1974) and Zadik et al (1977) came to similar conclusions.

Ozturk and Ozturk (1990) investigated a number of parameters and found that feeding patterns were much less important than ways of falling asleep in the aetiology of digit sucking habits.

Despite the weight of the evidence against feeding method influencing non-nutritive sucking, Golden (1978) and Shoaf (1979) both reported thumb sucking to be more common amongst breast-fed children and Larsson (1975) found a negative relationship between breast-feeding and the development of dummy and finger sucking habits, but only if breast-feeding had lasted 6 months or longer.

In similar findings to those of Ozturk and Ozturk (1990) it was reported by Wolf and Lozoff (1989) that whether or not a parent is present when a child actually falls asleep is an important factor in the development of thumb sucking However, where the child sleeps or how the child is fed were considered to be much less important.

It would appear, as discussed previously, that digit sucking is more common amongst girls beyond the first year of life, and so consideration as to why this is so may give clues as to the aetiology of the habit. Honzik and McKee (1962) suggested that this is a true sex difference and not simply a result of different child rearing practices for boys and girls or different levels of activity between the sexes. The authors hypothesise that the observation is due to girls' greater "orality" and reflects a greater cutaneous sensitivity and pleasure from tactile stimulation. In contrast, Larsson (1985) believed that this sex difference may indeed be an expression of the generally more passive demeanour of girls compared to boys. The author also used the sex difference to support the learned behaviour theory for digit sucking, since digit sucking is more common amongst females while this is the sex considered to have fewer mental disturbances.

When considering prevalence of sucking habits, it was mentioned that a number of workers found that a negative relationship exists between prevalence of dummy sucking and prevalence of digit sucking. (Zadik et al 1977, Larsson and Dahlin 1985). Larsson (1985) also found this to be the case, but made the observation that initial dummy sucking has increased in recent years to a greater degree than initial digit sucking has decreased. This evidence further supports the concept of unmet sucking urge being responsible for the development of digit sucking habits.

Eisman (1990) reported to the International Symposium on

Feeding and Dentofacial Development at Oslo that indeed infants are seven times less likely to develop digit sucking habits if they receive a dummy in time, and that while dummy sucking habits are given up relatively early, digit sucking is much more likely to become prolonged. Larsson (1985) also found that digit suckers had much more difficulty in breaking their habits than did dummy suckers, and pointed out that about half of those who begin a digit sucking habit still do so at the age of seven years.

The hypothesis that abrupt weaning from either the breast or bottle may contribute to acquiring an oral habit has been investigated by Sewell and Mussen (1952), who found that no such relationship exists. Jacobson (1979) however pointed out that sucking reaches it's maximum intensity at four months old, and that weaning from a liquid to a solid diet before this age may cause the child to suck objects, most commonly the thumb, to satisfy an emotional need.

In an interesting paper, Murray and Anderson (1969) looked into incisor proclination amongst children who suck their thumbs and found, in agreement with many other authors that there was an increase in overjet. When a subgroup who all suffered from allergic rhinitis were considered, the increase in overjet was found to be much more severe. Allergic rhinitis is associated with both nasal and palatal itching and it was postulated that children who suffer from allergic rhinitis tend to suck their thumbs more in an attempt to relieve the itching, and that this increased sucking is the cause for the significantly worse overjets. If this hypothesis is true, then allergic rhinitis would have to be considered as one of the aetiological factors for digit sucking.

Traisman and Traisman (1958) were unable to find a significant difference in prevalence of digit sucking amongst only children and children with between 1 and 4 siblings. Furthermore no correlation was observed for the habit between twins or between twins and their siblings. Anke (1972b) was also unable to detect any relationship between a child's position in a line of siblings and the presence of prolonged digit sucking habits. It would appear therefore that these factors are not of aetiological significance for digit sucking.

Thumb sucking has not only been reported amongst infants but also can be observed on ultrasound scans of the unborn foetus. Furthermore Hepper, Shahidullah and White (1990) suggested that identification of handedness may be determined by the prenatal observation of thumb sucking. In their study 212 foetuses were observed sucking their right thumb while only 12 were observed sucking their left thumb. These figures are not dissimilar to the 90:10 ratio for right and left handedness. The observation that foetuses suck their thumbs in utero is of interest since it would suggest that indeed there does exist an innate sucking urge. The observation detracts from the argument that digit sucking is a result of emotional insecurity, for surely there can be no more emotionally secure place than in the mothers womb.

In summary it is therefore possible to make the following comments regarding the aetiological factors associated with digit sucking habits:

1. Initial sucking habits are most probably a result of the infant having a surplus sucking urge which has to be fulfilled by non-nutritive sucking.

2. The continuation of initial habits into prolonged habits is as a result of simple learned behaviour.

3. Concepts of habit aetiology based on Freudian theory are not extensively supported in the literature.

4. As yet it is difficult to identify why sucking habits are more common amongst girls than boys but different child rearing practices, more passive demeanour in females and increased "orality" in girls have all been postulated.

5. Digit sucking is almost universally found to be lower amongst populations where dummy sucking is possible compared to where dummies are not available. Exposure to a dummy at the stage of development of initial sucking habits would therefore appear to be a

negative aetiological factor for the development of initial, and consequently prolonged, digit sucking habits.

6. Initial sucking habits are much more likely to become prolonged sucking habits if they involve digits compared to dummies.
7. There is little support for a link between different feeding patterns or size of family/position in family contributing to the aetiology of digit sucking habits.

E. Effects of digit sucking habits.

The effects of digit sucking habits have always been somewhat controversial, both in the lay press and the orthodontic literature. However in more recent times there has been more consensus although some of the finer detail remains under debate. There would appear to be little doubt that sucking habits can cause dental malocclusion. Popovich (1966) reported an incidence of 61% for serious cases of malocclusion among finger sucking 10 year olds with a corresponding figure 31% for children without such a habit. Kohler and Holst (1973) examined 4 year old children and found that malocclusion was significantly more frequent among children with earlier or persisting digit sucking habits compared to children with no such habits.

Considering the effects of digit sucking habits on the dentofacial region in greater detail, Proffit (1993) stated that sucking habits in the primary dentition have little if any long term effect while persistent habits which continue during the eruption of the permanent dentition can cause malocclusion. Proffit listed the possible consequences as flared and spaced maxillary incisors, lingually positioned mandibular incisors, anterior open bite and a narrow maxillary arch. These basic features were well classified by Larsson (1987) who categorised the effects on the dentofacial region as:-

(i) Vertical effects.

(ii) Anteroposterior effects.

(iii) Transverse effects.

Two main approaches have been followed in assessment of the effects of habits on the dentofacial region. Most studies have concentrated on recording the characteristics of the dental occlusion either directly from mouth examination or indirectly from orthodontic study models. The second approach, which is less widely represented in the literature is that of cephalometric analysis, using cephalometric lateral skull radiographs. Indeed, there have been few comprehensive cephalometric studies of digit suckers. The literature review below details published work on the effects of habits on the dentofacial region according to the three categories listed above, and for the type (occlusal or cephalometric) of analysis carried out.

Additionally, a number of miscellaneous effects have been reported and are worthy of mention. The effects of habits on the thumb or finger involved are of orthopaedic interest rather than orthodontic and are not discussed here.

(i) Vertical effects.

(a) Occlusal studies.

Analyses of the vertical characteristics of occlusion generally concentrate on the incisor overbite (or lack of it). Larsson (1987) stated that in the young child the vertical effect of digit sucking is not usually as severe as that of dummy sucking. A lack of firm incisal contact may develop, and an anterior open bite may result in more prolonged cases. The most extreme anterior open bites were considered to occur with habits prolonged into the eruption period of the permanent dentition. The anterior open bite was thought to be mainly a consequence of reduced alveolar growth. The relationship between digit sucking and anterior open bite appears to be well accepted in the literature (Baalack and Frisk 1967, Bowden 1966, Gardiner 1956). Larsson and Ronnerman (1981) attempted to explain the pathogenesis of the condition by examining the clinical crown lengths of thumb suckers and non thumb suckers. It was found that the thumb sucker group had significantly greater clinical crown length than the controls. This was interpreted as signifying that reduced alveolar growth, and not simply impeded eruption of the incisors, was the pathogenesis of the anterior open bite in prolonged digit suckers. However, this hypothesis should be accepted with caution, as thumb sucking also results in proclination of the incisors, and the longer clinical crown length may be a result of the teeth being positioned further forward in the alveolar process. In addition Proffit (1993) implicated the effect of over-eruption of the posterior teeth during digit sucking in the pathogenesis of the anterior open bite, and pointed out that 1mm of eruption posteriorly can produce 2mm of bite opening effect anteriorly.

Lindner and Modeer (1989) reported that overbite was more negatively influenced by dummy sucking than by digit sucking, and found a significant relationship between reduced overbite and duration of such habits. Rodregues de Almeida and Ursi (1990) pointed out that the morphology of the anterior open bite in habit cases is determined by the type of habit, with digit sucking producing a labial inclination of the maxillary incisors, and a dummy sucking habit resulting in a more circular distortion of the vertical position of both the maxillary and mandibular incisors. The authors also considered that the anterior open bite is a consequence of impeded eruption of teeth rather than alveolar growth modification as suggested by Larsson and Ronnerman.

Larsson (1972) reported an extensive study of 32 variables recorded for 116 10 year old finger suckers compared to 100 similar children without such habits. 2 of the variables which were determined from study models related to vertical characteristics. In agreement with the consensus of opinion, a significant difference was observed in the incisor overbite between the groups, with the digit suckers' overbite being reduced. Indeed the reduction in overbite was so substantial that the mean value indicated an anterior open bite. The height of the palatal vault was also measured at the level of the first permanent molars, and for this variable no significant difference was observed between the digit suckers and the controls. Conversely Hanson and Cohen (1973) did find a correlation between digit sucking and palatal vault height.

In a follow-up of the same subjects at 16 years of age, Larsson (1978) investigated the longer term implications of sucking habits, and compared a range of occlusal and cephalometric variables between subjects who had previously had prolonged digit sucking habits and those who had never had such a habit. Interestingly, many of the differences which had been observed at 9 years of age were no longer present at the older age, indicating that cessation of the habits had resulted in spontaneous correction. No significant difference was observed in the occlusal variable "overbite" between the previous suckers and those who had never sucked.

The effect of digit sucking in the vertical dimension has been demonstrated to be constant for different races by Kerosuo (1990) who observed that anterior open bite was significantly more common among young finger suckers (mean age six years) in both Finland and Tanzania compared to non finger sucking control groups from each nation.

Although the anterior open bite is considered by some to be a result of reduced alveolar growth, stopping the habit frequently results in spontaneous correction by accelerated alveolar growth even if the habit has continued well into the mixed dentition period. (Larsson 1978). Cases where the habit continues beyond the pubertal growth spurt are much less likely to be corrected spontaneously.

Yoshida et al (1991) considered that the anterior open bite observed in digit suckers can lead to difficulty in mouth closure and habitual mouth breathing, and also result in an anterior tongue thrust which affects oral functions such as swallowing and mastication. Van Norman (1985) considered that the majority of children with anterior open bite also have a tongue thrust, and quoted a figure of 98% for this relationship.

Melsen et al (1979) in a study of 725 Danish children found that previous sucking habits had a significant effect on swallowing pattern, with digit suckers showing an increased tendency towards tongue thrust swallowing and teeth apart swallowing. The authors cited the work of Straub (1960), Hanson and Cohen (1973) and Subtelny and Subtelny (1973), who had all demonstrated a link between these types of swallowing pattern and malocclusion and suggested that an indirect association between sucking and malocclusion, via swallowing pattern may exist. Despite this observation, Larsson (1987) considered that alveolar growth and tooth eruption following cessation of a digit sucking habit is sufficient to close down an anterior open bite, even if a tongue-thrust swallowing pattern has been adopted to accommodate the anterior open bite. An additional complication reported by the author is experienced when a subject who stops a sucking habit has a postnormal sagittal occlusal relationship. In this case should the anterior open bite close down following the cessation of the habit the incisors do not achieve positive contact and a deepened bite may result.

Most digit sucking habits are to some degree asymmetrical with implications for the vertical features of the malocclusion produced and this relationship was stressed by Larsson (1987).

(b) Cephalometric studies.

An extensive cephalometric analysis of some 320 9 year old children in Sweden was reported by Larsson (1972b). The children were grouped according to their sucking habits as either persistent digit suckers (n=116), previous dummy suckers (n=104) or children with no history of sucking habits (n=100). A total of 15 cephalometric variables were analysed, 8 of which can be considered as measuring vertical characteristics. Larsson found no significant difference in either upper anterior face height nor total anterior face height between the digit suckers and the control group of non suckers. When posterior face height measurements were considered, no significant difference was observed in the total posterior face height measured from sella to the perpendicular intersection with the mandibular plane. However, upper posterior face height, measured from sella to the perpendicular intersection with the maxillary plane was shown to be significantly increased in the digit sucking group. The angulation of the maxillary and mandibular planes relative to the cranial base (sella - nasion line) was investigated, and it was found that while no significant change in angulation of the mandibular plane occurred, the maxillary plane angle to the cranial base was significantly reduced in the digit sucking group. This represents a rotation of the maxillary plane, upwards anteriorly and downwards posteriorly. The remaining 2 vertical measurements related the position of the incisal edges of the maxillary and mandibular incisors to nasion, and it was found that for the digit suckers, maxillary incisors were positioned in a significantly higher location. No significant difference was observed for the mandibular incisal edge height.

Following-up the same subjects at 16 years of age, Larsson (1978) revealed that following cessation of the habits, the majority of cephalometric vertical variables reverted to being similar for the previous suckers and the controls, although upper anterior face height was found to be significantly reduced in the previous digit suckers. It is notable that the angulation of the maxillary plane relative to the cranial base, which was significantly different in the study of 9 year old persisting suckers, was no longer significantly different at 16 years of age, when the habits had stopped.

Brenchley (1991) investigated a group of patients, all of whom had Class 2 Division 1 malocclusions. The subjects were divided into those who were digit suckers at the start of orthodontic treatment, those who had a history of previous sucking and those who had never sucked. Changes in cephalometric variables during orthodontic treatment were analysed. It was observed that during treatment the digit suckers demonstrated a rotation of the maxillary plane (with the anterior region moving in an inferior direction and the posterior region moving in a superior direction) to a significantly greater degree than the control group of non suckers. Similarly the ratio Upper Face Height : Lower Face Height was found to increase significantly more during treatment for the digit suckers compared to the controls. These observations were interpreted by the author as indicating that digit sucking does influence the angulation of the maxillary plane, and that following cessation of the habit, favourable changes may occur which assist in the correction of the malocclusion. Taft (1966) also reported that digit suckers had a tipping of the occlusal plane, upwards anteriorly and downwards posteriorly, and that the distance from sella to the landmark pterygomaxillare was significantly increased.

(ii) Anteroposterior effects.

(a) Occlusal studies.

When considering the anteroposterior characteristics of occlusion, the two main areas of interest are the incisor relationship as measured by the overjet, and the buccal segment relationship. Occlusal analysis can only identify basic incisor relationship discrepancy, but determination of the cause of the discrepancy (e.g the angulation of the maxillary or mandibular incisors) requires cephalometric analysis as described in the next section.

The effect of initial sucking habits on the anteroposterior dimension in the young infant's dentition is rather insignificant. The only noticeable feature may be some slight spacing of the upper anterior teeth with a mildly increased overjet. However this effect will increase with age as the habit continues, and by the time that the permanent dentition is developing may be quite significant. Larsson (1987) in agreement with Graber (1958) distinguished between two modes of digit sucking; either with a finger sitting passively between the upper and lower incisors, dorsal surface uppermost or with a finger or thumb positioned palmar surface uppermost. The latter mode is by far the more common of the two and it is potentially the more damaging since the finger acts as a lever, applying force to the palatal surface of the upper incisors. The force applied by the lever acts in a vertical direction as already mentioned to restrict vertical alveolar growth while the horizontal component acts on the maxillary incisors to cause proclination, protrusion, anterior displacement and overall arch lengthening. Soft tissue deformity may also occur with incompetent lip function. Larsson suggested that once a habit has been broken, and providing that soft tissue function is normal, the proclined incisors often become retroclined as a result of lip pressure. In combination with the overall maxillary arch lengthening previously mentioned this movement results in a Class 2 Division 2 type incisor relationship.

Murray and Anderson (1969) investigated 354 Vancouver school children and reported that excessive incisor overjet was twice as common in digit sucking children compared to non digit suckers.

In a large and complex study of occlusal conditions among 8158 Swedish 12 year olds, Baalack and Frisk (1971) found that children with digit sucking habits after the age of 7 years showed a significantly increased overjet compared to children who had either given up their habit before the age of 6 or who had never had such a habit. The authors were unable to find any evidence to prove that a postnormal molar relationship was more common among digit suckers. Myllarniemi (1973), cited in Melsen et al (1979) also found no relationship between sucking habits and postnormal molar relationship. In conflict with this Larsson (1972b) demonstrated that digit sucking habits may cause a postnormal molar relationship, and in common with Humphries and Leighton (1950) found that if a child persists in sucking one thumb rather than another, this postnormal molar relation may be unilateral. Melsen et al (1979) also found a positive correlation between the frequency of distal occlusion and finger sucking, as did Popovich and Thomson (1973). Melsen's study also demonstrated a positive correlation between finger sucking and extreme overjet.

Examining 2500 Indian children aged 2-6 years old, Nanda et al (1972) found significantly more Class 2 molar relationships among digit suckers than in those without such habits. Thumb sucking children were also found to have significantly greater overjets.

Bowden (1966) assessed anteroposterior skeletal base relationship clinically among 116 Australian children and observed a significantly greater prevalence of Class 2 relationships in digit sucking children. The study was of a longitudinal design, and when the molar relationships of the digit suckers were followed, no changes were observed between the ages of 2 and 8 years old. It was suggested that if a digit sucking habit is to influence the molar relationship, then the change must be brought about during the first 2 years of life.

(b) Cephalometric studies.

Using cephalometric techniques, it is possible to investigate a number of anteroposterior variables which may be influenced by digit sucking. Of particular interest are the angulation of the maxillary and mandibular incisors relative to the maxillary and mandibular planes respectively, and the degree of maxillary and mandibular prognathism relative to the cranial base.

Larsson's 1972 study of 116 9 year old children is one of the most comprehensive assessments of the problem. The maxillary incisors were found to be significantly more proclined among digit suckers, with a mean angle of $108.8^{o}$ relative to the maxillary plane compared to $101.4^{o}$ for the control group. This relationship was also confirmed by the measurement of the position of the maxillary incisal edge relative to the line joining the reference points Nasion and Gnathion. This distance was significantly increased for the digit sucking group. No such differences were observed for the angulation of the mandibular incisors relative to the mandibular plane. When consideration was given to prognathism, the maxilla was observed to be relatively further forward in the digit sucking group as measured by the variable SNA. ($83.15^{o}$ for digit suckers, $81.31^{o}$ for the controls.) No significant difference was observed between the groups for the variable SNB. Larsson (1978) reassessed the same group of children at 16 years old to determine whether cessation of the habit could lead to the variables returning to "normal" by the age of 16. While the angulation of the incisor teeth was no longer found to be significantly different between those who had previously sucked their digit and those who had never had such a habit, the variable SNA was still significantly greater. In addition, the anteroposterior length of the maxillary skeletal base was observed to be significantly increased for the group with a history of previous digit sucking.

There would appear to be some disagreement between authors as to the nature of the effect of digit sucking on the lower incisors. Backlund (1963) reported that the lower incisors become proclined, probably as a consequence of the tongue pressing against these teeth during the sucking action. For this to occur, the anteriorly directed force of the tongue would clearly have to be more influential than the posteriorly directed force of the digit. Larsson's cephalometric study found a small but not statistically significant increase in mandibular incisor proclination, which supports the view of Backlund (1963) as well as Taft and Hempstead (1966). In contrast, some authors have found prolonged digit suckers to have retroclined mandibular incisors (e.g. Gardiner 1956), and Subtelny (1973) found these children to show greater mandibular movement during sucking, increasing the posteriorly directed force. Martinez and Hunckler (1986) also considered that lower incisors become retroclined by digit sucking rather than proclined.

Willmot (1984) reported a cephalometric analysis of two monozygous twins aged fourteen years, one of whom sucked her thumb, the other did not. Interestingly, the majority of measurement were similar for both girls (SNB, Upper Incisor to Maxillary plane, Lower Incisor to Mandibular Plane, Maxillary/ Mandibular Plane Angle, Cranial Base to Maxillary Plane Angle,). Sella-Nasion-A Point was the only variable found to be markedly different, being 3 degrees greater in the thumb sucking twin. While the results of such a small study must be viewed with caution, this provides a basis for further assessment of craniofacial morphology amongst digit suckers.

(iii) Transverse Effects.

The influence of digit sucking on transverse dentofacial characteristics is probably the area of greatest controversy. All the published studies have concentrated on determination of variables directly from the teeth or indirectly from study models, and no cephalometric analyses of transverse features (using Posterio-Anterior cephalometric radiographs) have been reported.

The implication of digit sucking as an aetiological factor for the development of posterior crossbites in the deciduous dentition has been well established. Lindner and Modeer (1989) investigated 76 four year old children who all had unilateral posterior crossbite. All except 1 were found to have a history of a sucking habit between the age of two and three years, and at the time of examination 63% still had such a habit, with dummy sucking (78%) being dominant. The authors concluded from their statistical analysis that both "intensity" (measured in hours per day) and "duration" of sucking habits have a significant negative influence on maxillary arch width. Dummy sucking was shown to be more detrimental to arch width in the canine region when compared to digit sucking, although this may be related to the fact that dummy suckers have a higher mean sucking time than digit suckers.( Modeer et al 1982)

Kohler and Holst (1973) also demonstrated a higher prevalence of crossbite in 4 year old children with sucking habits compared to non suckers. Highest levels were recorded for children with continuing dummy sucking habits, followed by those with continuing digit sucking habits, with children with discontinued habits having still lower levels of crossbite. Lowest levels were recorded for children with no habit or history of one. The results were very similar to those published by Larsson (1975).

Larsson et al (1990) reported to the International Symposium at Oslo on a study of three year old children in Sweden and Norway. They found that the maxillary intercanine width was narrower in sucking groups compared to non-sucking groups, although no difference was seen for mandibular intercanine width. In agreement with Lindner and Modeer (1989) dummy sucking was found to have a greater effect on intercanine width than digit sucking. The Swedish sucking group was found to have a prevalence of 21% for posterior crossbite, while the corresponding figure for non-suckers was 0-7%. Kerosuo (1990) also reported a significantly increased frequency of crossbite amongst six year old Finnish children who had sucked a digit beyond the age of one year compared to controls who had stopped by that age (15% and 4% respectively.).

Larsson (1987) described a probable pathogenesis for unilateral crossbites in these cases whereby the presence of a digit in the upper mouth causes the tongue to sit in an unusually low position, leaving the upper arch with reduced lingual support, and the lower arch with increased lingual support. As a result the upper arch may become narrower (most noticeably in the canine region) and to some degree the lower arch wider, producing occlusal interferences which guide the mandible into a displaced path of closure to one side or another. Day and Foster (1971), considering the aetiology of buccal crossbite, suggested that it is in fact negative pressure generated in the palatal vault which contributes to the development of buccal crossbites in these cases.

While it has been demonstrated by numerous authors that dummy and digit sucking habits are an important aetiological factor for posterior crossbites in the deciduous dentition, it has been more difficult to prove such a relationship for the permanent dentition. Larsson (1990) found that the prevalence of crossbite in the permanent dentition of children who had sucked a finger or dummy until 4 years of age was similar to that for children who had never had such a habit. Furthermore the prevalence of crossbite amongst a group of ten year old children who had just stopped a sucking habit was in the same range of 12-15%. In another study of 252 children with prolonged finger-sucking habit , mean age 10 years, Larsson (1983b) found that there was not an elevated prevalence of posterior crossbite in either digit suckers nor dummy suckers, compared to other studies of non-habit groups. The author postulated that since the digit is not usually inserted further into the mouth than the distal edge of the second deciduous molar ( or second premolar) the transverse contracting effect is less significant at the level of the first permanent molars. Bowden (1966) and

Ruttle et al (1953), could find no effect of digit sucking on the intermolar width. Larsson (1972) measured intermolar width in the upper and lower arches of 9 year old digit suckers (n=116) and found no significant difference when compared to non suckers.

Posterior crossbite was found to be significantly more common in seven year old finger suckers compared to controls by Hannuksela and Vaananen (1989), and Martinez and Hunckler (1986) also stated that digit sucking causes a posterior cross bite in the permanent dentition, on the ipselateral side as the sucking due to increased buccinator activity. Popovich (1966) also considered that prolonged digit sucking is associated with reduction of the intermolar width in both the maxillary and mandibular arches. Willmot's study of a pair of monozygous twins with and without digit sucking habits at 14 years of age (1984) revealed that while the maxillary arch was somewhat constricted in the thumbsucker, a more substantial difference was seen in the case of mandibular arch width which was some 4mm greater for the thumbsucking twin, and contributed substantially to her bilateral posterior crossbite.

(iv) Miscellaneous effects.

Linge and Linge (1991) reported that a history of digit sucking beyond the age of seven was found to significantly contribute to apical root resorption during orthodontic treatment. However, this may simply be due to the fact that digit suckers tend to have increased overjet and that this feature is the significant factor for apical resorption in this situation. Rubel (1986) also reported that digit sucking habits may influence the normal physiological resorption of maxillary primary incisors, although the clinical significance of this is relatively small. Taylor and Peterson (1983) reported a study of 98 randomly selected children aged two to four years and looked at occlusal radiographs. It was found that 59% with digit sucking habits demonstrated atypical root resorption patterns on maxillary deciduous incisors compared to only 8% for non digit suckers, and it was concluded that exfoliation related root resorption may be accentuated or hastened by digit sucking habits. The consequence of premature exfoliation of the deciduous incisors may be that the permanent incisors are delayed in their eruption, providing an extended period during which tongue thrusting habits may develop. (Van Norman 1985)

Kohler and Holst (1973) found that caries levels among 4 year old children who sucked dummies were significantly higher than children of the same age who sucked digits. Larsson (1975) also reported significantly lower caries levels among digit sucking 4 year olds compared to either dummy suckers or indeed non suckers. This association should not however be taken at face value, since dummy sucking appears to be more common among the lower socio-economic groups, who are also the group who demonstrate highest caries levels in Western cultures. The relationship is worthy of further investigation, however, for it is possible that the act of digit sucking may stimulate salivary flow which in turn can help to neutralise plaque acid following exposure to sugars.

Larsson (1975) asked three questions relating to quality of speech when investigating 3349 4 year old children. Although no mention of the effects of digit sucking on speech were made, it was stated that no difference could be detected in prevalence of speech problems between dummy suckers and non suckers. It seems likely that digit sucking would also exert little if any influence on speech. In the same paper, Larsson postulated that sucking habits create negative pressures which may be of significance in the development of otitis. A significantly increased proportion of continuing dummy suckers had a history of otitis compared to controls, but no such relationship was seen to exist for digit suckers.

In summary it is therefore possible to make the following comments with respect to the effects of digit sucking habits on the dentofacial region:

1. Digit sucking habits are associated with increased prevalence of malocclusion.

2. Such habits appear to have influence in the vertical, anteroposterior and transverse dimensions of the dentofacial region.
3. In the vertical dimension, the principal effect is that of reduced incisor overbite or indeed anterior open bite, particularly when the habit is prolonged.
4. From cephalometric studies, it appears that prolonged digit sucking may cause a rotation of the maxillary plane, upwards anteriorly and downwards posteriorly.
5. In balance, palatal vault height does not appear to be substantially influenced by digit sucking.
6. In the anteroposterior dimension, the main influence appears to be a proclination of the maxillary incisors, resulting in increased overjet, an increase of the angle between the maxillary incisors and the maxillary plane and a decrease in the interincisal angle.
7. The influence of digit sucking on the mandibular incisors would appear to be variable, with some reports of proclination and some reports of retroclination. It is possible that these differences represent different types of sucking habit.
8. Sucking habits can result in a reduction in the transverse dimension of the maxillary arch during the deciduous dentition most significantly in the canine region.
9. There is considerable debate about whether or not

sucking habits cause buccal crossbites in the permanent dentition. If any effect does exist, it is likely to be small and concentrated in the more anterior regions of the arches.

10. A number of miscellaneous effects of digit sucking have been reported, but all are of minor clinical relevance compared to the implications for the dental occlusion.

F. Treatment of digit sucking habits.

Having acknowledged that digit sucking may exert harmful influences on the dentofacial region, the possibilities for treating the problem merit consideration. The fundamental rationale for such treatment is that by not digit sucking, the individual is removing one harmful environmental effect from their dentofacial development. Treatment of malocclusion exacerbated by digit sucking is not the subject of this review, and is well covered in standard orthodontic texts. (Proffit 1993)

The first mode of treatment for habits is that of primary prevention. By definition a habit is an activity which is hard to give up, and so the concept of preventing it's initiation is attractive. As already discussed, digit sucking usually starts early in life, at a time when simple education and reasoning are not feasible. Modern feeding methods and well nourished breast feeding mothers mean that infants are efficiently fed, and often have a surplus sucking urge which has to be fulfilled. (Larsson and Dahlin 1985). Consideration towards preventing digit sucking has therefore focused on the possibility of providing an alternative escape for the unmet sucking urge in the form of a "dummy" or "pacifier".

There have been no reports of interventional studies to investigate the influence of making dummies available on prevalence of digit sucking, although Eisman (1990b) reported encouraging preliminary results with a preventively designed comforter. However, evidence from observational studies is convincing. Zadik et al (1977) studied prevalence rates for digit sucking in a number of different Israeli Kibbutz, and found highest rates in a Kibbutz where dummies were withheld. Larsson and Dahlin (1985) charted prevalence rates for initial dummy and digit sucking in Sweden from 4 independent studies between 1949 and 1983. It was shown that while prevalence rates for dummy sucking had increased during that time, the corresponding figure for digit sucking had decreased. A trend towards an increase in the total prevalence of initial habits was also observed, and was attributed to the fact that the increase in dummy sucking had been slightly greater than the decrease in digit sucking. De Boer (1976) and Buttner (1969 - Cited in Larsson and Dahlin 1985) both observed elevated prevalence of digit sucking in regions were dummy sucking was rare. Kristensen

(1990) reported that digit sucking was much more common among children who do not use a dummy.

It seems likely, therefore, that making dummies available to the young infant does act as a preventive measure with respect to the development of digit sucking habits. An important consideration before recommending the use of dummies universally, is the possibility that doing so would replace one harmful habit with another. Certainly dummy sucking can lead to malocclusion in a similar way to digit sucking. Indeed Larsson (1975) found that the anterior open bite observed in dummy sucking 4 year olds was more severe than that in finger suckers of a similar age. The same author in 1986 pointed out the even more disastrous effects of adopting an "atypical" dummy sucking position on the dentition. In the transverse dimension, several authors have demonstrated an increase in the prevalence of posterior crossbite in the deciduous dentition among dummy suckers (Kohler and Holst 1973, Larsson 1975). Svedmyr (1979) and Lindner and Modeer (1989) found that the effect of dummy sucking in the transverse dimension was greater than that of digit sucking, especially in the maxillary intercanine region. Despite these detrimental effects of dummy sucking on the occlusion, an important factor is that they appear to be transient, and tend to correct spontaneously on cessation of the habit. Larsson (1978) investigated the effect of previous dummy sucking on the occlusion of 16 year old children, and found that while a reduction in face height and reduction in the inclination of the mandibular plane were detected, these features were not detrimental. Furthermore the orthodontic treatment need of previous dummy suckers was less than that of non suckers, and substantially less than that of previous digit suckers. It was speculated by the author that dummy sucking caused muscle activity which had a beneficial effect on the development of the dental arches.

In using a dummy, it is important that no attempt is made to augment the pacifying effect by filling or coating the dummy with sweet, sugary substances with a high cariogenic potential. The catastrophic effect on the dentition of the slowly released sugar over a prolonged period of time has been well established by Winter et al (1971) and Holt et al (1982) among others and appropriate dietary advice should therefore be made available to parents.

The most significant benefit of dummy sucking over digit sucking habits is the relative age at which the habits tend to cease. The literature provides strong evidence that children who develop dummy sucking habits give up at a much earlier age on average than do digit suckers. (Bowden 1966, Kohler and Holst 1973, Ravn 1974, Larsson 1975, Modeer 1982, Ogaard 1989, Kristensen 1990)

Bringing the evidence together, it would seem reasonable to encourage the provision of a dummy as a preventive measure with respect to digit sucking, especially if an infant demonstrates surplus sucking urge. While dummy sucking may have harmful short-term effects on the occlusion, these are usually restricted to the deciduous dentition and correct spontaneously on cessation of the habit, which usually occurs at a significantly earlier age than digit sucking. Care should be exercised in ensuring that children who do have a dummy sucking habit are using the dummy in the manner which it was designed for, and that no sugary substances are being applied to the dummy prior to use.

Of those children who do develop and maintain a digit sucking habit, a significant number experience difficulty in breaking their habit and present themselves to medical or dental practitioners asking for help. In the United Kingdom, Orthodontists have often provided a treatment service in this respect although no figures have been published to quantify the impact of the problem on Hospital Orthodontic Clinics. Clinical experience would suggest that demand for help in breaking habits is relatively high. The reasons for wishing to stop will vary from case to case but largely relate to either embarrassment or an awareness that the habit is causing detrimental effects to the dentition. These observations may be those of the patient, their parents or their family dentist.

Historically, the appropriateness of intervening to help break habits has been a controversial issue. As recently as 1965, it was suggested that there was no indication for intervention (Apley, 1965). However this paper appeared to be based on an underestimation of the impact of digit sucking by today's knowledge and received a mixed response from the dental profession at the time. (Pitt-Steele 1965, Nichol and Stephenson 1965). Publications in the 1950's and 1960's appear to be dominated by unsubstantiated opinion and anecdotal evidence. For example Korner and Reider (1955) reported results of treatment of just three cases aged 3 to 6 years and found one child to have drastic new symptoms such as "night terrors, day wetting and sleep disturbance" as a consequence of using an orthodontic appliance to help break a habit. Supporting an alternative view, Mack (1951) questioned how much harm is done to the mental health of the child by the insertion of an appliance to help break a habit, and pointed out that toilet training is a frustrating and stressful stage of child development, but does not result in mental disturbances.

More recent opinion, based on scientific evidence would suggest that a balanced approach is indicated, with no treatment really necessary during the deciduous dentition but treatment indicated to help break habits once the eruption of the permanent incisors begins. (Baalack and Frisk 1971, Proffit 1976, Gellin 1978, Proffit 1993). Larsson (1988) stated that attempts to break a digit sucking habit should only be made if the patient has a postnormal (Class 2) molar relationship or is about to get one. The author considered that the presence of an anterior open bite was not sufficient reason for treatment unless it seemed likely that the habit would continue until after puberty, when spontaneous correction is less likely. Leivesley (1984) considered that full orthodontic treatment should not be undertaken until any habits have been brought under control.

Addressing the psychoanalytical theory of digit sucking, and in particular the suggestion that interfering with the habit is likely to produce serious symptoms, Davidson et al (1967) conducted detailed psychological assessments of 18 persistent digit suckers and failed to demonstrate any consistent psychological abnormality. Similarly, arresting the habit with a palatal crib failed to produce any significant increase in alternative symptoms. The evidence was used to support the learned behaviour approach to digit sucking. Similar findings were reported by Larsson (1972a) who treated 112 nine year old children, and compared 3 methods of breaking habits with no treatment. No differences in respect of mental symptoms were observed either between the treatment groups and the control group, nor between the different treatment groups. No substitution symptoms were recorded among the children who broke their habits as a result of treatment.

If one accepts the philosophy that there are indications for offering habit breaking treatment, a range of different methods can be used, all of which have at some time been promoted. Methods can be broadly grouped as "physical" and "non-physical" although regimes described in the literature often combine aspects of both.

Several authors have recommended the use of an orthodontic appliance with a palatal crib.( e.g. Massler and Chopra 1950, Graber 1958, Jaraback 1959, Gellin 1978, Proffit 1993). The effectiveness of the technique has been tested by Larsson (1972a) who examined 112 nine year old children with persistent habits. Three different types of treatment were tested, (Palatal crib Therapy, and two non-physical methods, Positive Reinforcement and Negative Reinforcement) and all were found to bring about significant reductions in digit sucking habits over a 2 $^1/_2$ month period when compared to a group of controls who received no form of therapy. No significant difference in the relative effectiveness of the three different types of treatment was observed. The type of palatal crib used by Larsson had spurs and was welded to upper molar bands which were then cemented in place.

Haryett et al (1967) reported a similar evaluation of treatment techniques on children aged 4 or over with persisting habits and compared 5 regimes with a non treated control group. The regimes studied were: 1. No treatment, 2. Psychological treatment, 3. Passive palatal arch, 4. Palatal arch and psychological treatment, 5. Palatal crib, 6. Palatal crib and psychological treatment. It was observed that the palatal crib with spurs was the most effective way of arresting the thumb sucking habits. Psychological treatment, which consisted of education and encouragement in the form of rewards for not sucking, and palatal arch treatment were found to have no significant effect in reducing thumb sucking. The same study also reported on the development of alternative habits subsequent to cessation of thumb sucking. Alternative habits were found to develop no more frequently in those who did stop sucking than those who did not.

A follow-up of the same material three years later was reported by Haryett et al (1970) and investigated the longer term effectiveness of crib therapy. The success rate in permanently arresting the habit was reported as 100% at 1 year, and 91% at 3 years due to a small number of cases relapsing. Furthermore, the authors analysed their results to determine the optimum length of treatment with a palatal crib. 3 months duration of treatment was found to be significantly less effective in breaking habits in the long term than either 6 months or 10 months of treatment, but no significant difference was observed between the 6 and 10 month treatment group. When 2 designs of palatal crib were compared, no significant difference in the effectiveness of cribs with or without spurs was observed. The same authors reported 3 minor disadvantages of the palatal crib; 1. A "temporary period of upset" 2. Difficulty with speech and 3. Difficulty with eating.

Gellin (1978) also recommended the palatal crib, but described it's use as an integrated part of a general balanced approach to the problem of digit sucking. The crib recommended by Gellin was soldered to molar bands, fabricated from 0.045-0.050 inch wire and incorporated no spurs. Gellin also advocated the use of removable appliances incorporating palatal cribs for certain cases where it was judged that the habit was especially meaningful, in order that the patient may remove it should the situation become intolerable. Larsson (1988) also considered valuable the use of a removable orthodontic plate with palatal crib for those children who have ceased their habit during daytime, but continue at night. A removable "Hawley" type orthodontic appliance, consisting of Adam's cribs on the first permanent molars and a labial bow, together with the addition of a palatal grid was the appliance recommended by Jacobson (1979). The reason given for preferring a removable design was that this enabled the child to remove the appliance in order to suck the thumb if it became necessary, thus avoiding any possible psychological effects.

Viazis (1991) described a modification of the fixed palatal crib appliance, designed to reduce the amount of laboratory and chairside time required. The "Triple Loop

Corrector" was constructed at the chairside from 0.036 inch wire and fitted into the lingual sheaths of upper first molar bands, and consisted of three loops placed in the palate behind the maxillary incisors. Likewise, Campbell (1984) described a modification of the simple palatal crib, by incorporating it into a fixed expansion appliance for the treatment of cases with buccal crossbite and persistent habits. The authors were unable to provide evidence regarding the efficacy of the appliances, but it seems unlikely that this would be substantially different to that of a conventional palatal crib.

As well as the palatal crib, a number of other "physical" methods for breaking digit sucking habits have been described although a significant lack of scientific evaluation exists. Friman et al (1986) investigated the effectiveness of painting a bitter tasting substance on the digits. The solution was a commercially available product "Stop-Zit", which contained 49% toluene, 19% isopropyl alcohol, 18% butyl acetate, 11% ethylcellulose and 0.3% denatonium benzoate. The solution was reported to be toxic only if swallowed in large amounts (such as a whole bottle). Only 7 children were included in the study, with an age range 3 to 12 years (mean 7). 100% success in breaking the habits was observed, with response times varying between 5 and 25 days. Habits remained broken at 6 month review. Other reported physical methods include alteration of the child's pyjamas to restrict the movement of the hands (Levin 1958), splints around the elbows (Klink-Heckmann and Bredy 1977) and wearing gloves (Benjamin 1967, Lassen and Fluet 1978). Martinez and Hunckler (1986) suggested the use of an adhesive bandage wrapped around the offending digit, and Jacobson (1979) suggested taking impressions of the thumbs and constructing soft acrylic splints with a vacuum forming machine. The splints were then perforated and tied on to the thumbs at night, breaking any possible seal during sucking. Lack of meaningful evaluation of these methods prevents their comparison with crib therapy.

In contrast to the previously described physical methods for treating habits, a number of authors have described non physical methods, often based on psychological theory. A common theme in many such techniques is that of "contingency management", whereby a positive reinforcement in the form of a reward is contingent upon the lack of any sucking. The types of rewards described vary and include being allowed to watch cartoons (Baer 1962), reading of bedtime stories (Knight and MacKenzie 1974) or being given pocket money (DeLaCruz and Geboy 1983). An integral part of such a program of positive behaviour management is the process of "monitoring" (Cipes et al 1986). Monitoring involves the regular observation of the child, usually by the parent, and the collection of data regarding presence or absence of the habit. Data collection is described using charts or cards upon which stars or ticks are collected when the child is observed not to be sucking their finger. Contingency contracts may then be established between the child and their parent, such that a reward will be gained when a predetermined number of stars have been collected.

The efficacy of the techniques involving monitoring and reinforcement was tested by Cipes et al (1986) on 11 children aged 5-9 years old. Parents were asked to monitor sucking behaviour on 8 predetermined occasions in each 24 hours, and recorded the absence or presence of the habit. Baseline figures were recorded over a 2 week period without the child's knowledge, and then a period of intervention was begun during which the results of the observations were recorded on a chart in a conspicuous position in the home. Substantial reductions in digit sucking were observed, and were maintained at a follow-up 6 months later. While presenting promising results, any study with such small numbers must be viewed with some caution.

Martinez and Hunckler (1986) stated that monitoring and reinforcement are only appropriate for children with infrequent habits of low intensity and supported an alternative behaviour modification technique called the "Habit Reversal Method" for more persistent cases. The technique, originally described in relation to digit sucking by Azrin and Nunn (1973), involves the teaching of competitive activities such as fist clenching or object holding when the urge to suck the digit occurs. Habit reversal was further evaluated by Azrin et al (1980) who compared the effectiveness of the technique with the technique of painting the digits with bitter substances. The mean age of the 32 subjects was 8.3 years, and 18 were give habit reversal therapy and 14 were give aversive taste therapy. At a three month follow-up of both groups, the reduction in sucking for the habit reversal method was significantly greater than that for the aversive taste method, with 47% and 10% respectively having completely stopped their habits. Furthermore the authors found that the benefit continued to the final review at 20 months, when it was observed that the reduction obtained using habit reversal therapy was almost as great as that reported by Haryett et al (1970) using a palatal crib.

Rinchuse and Rinchuse (1986) described a further technique for the treatment of digit sucking known as "reframing". With this method the aim is to change the emotional setting associated with the habit from being pleasurable to being dutiful and obligatory. The authors illustrated the technique by citing the case of a girl who persists in sucking one particular digit. The therapist explains to the child that the other nine digits may feel neglected, and that in order to be fair, she should suck each digit in turn for the same length of time. To enforce the new regime, the child is asked to keep a tally of how much time per day is spent sucking each digit. A study of 11 cases treated using the technique was reported, with 100% success in breaking the habits, and the authors proposed that a more formalised study would be appropriate to test fully their anecdotal findings.

With all the psychological therapeutic methods described an important theme is that of providing positive support and encouragement to the child rather than a negative, punishment based regime. Van Norman (1985) strongly supported the argument for helping children break their habits and described a three-stage process of 1. establishing a baseline of behaviour. 2. Utilization of positive motivational influence to make the child wish to stop their habit. and 3. A systematic program of reminders and positive reinforcement to enable the child to fulfil their desire to give up the habit.

In summary, it is possible to make the following comments with regard to the treatment of digit sucking habits.

1. It would appear that the provision of a dummy, used with care as an outlet for surplus sucking urge in the young infant, may have value in the primary prevention of prolonged digit sucking habits since dummy sucking has fewer long term damaging effects and tends to be given up at an earlier age.
2. Having consideration for the reversible effects of early digit sucking, intervention is only recommended

after the permanent incisors begin to erupt, and when the child acknowledges that a problem exists.

3. There is no support in the contemporary literature for the view that intervention with digit sucking habits results in mental symptoms or substitutional habits.
4. Treatment modalities reported are either physical or psychological, although the most balanced regimes incorporate features of both.
5. Physical treatment using an orthodontic appliance with palatal crib (with or without spurs) has been well demonstrated to be effective in breaking habits. Other physical methods which have been reported rely on more anecdotal evidence.
6. Psychological methods, based on different concepts of behaviour management therapy, have been reported to be effective although the published studies have tended to be rather small scale.
7. The decision whether or not to treat a digit sucking habit will depend very much on the individual patient, and a balanced, caring approach based on support and encouragement is indicated.
8. The possibility of more significant psychological disturbance should be borne in mind when dealing with these cases, although the frequency of this situation is rare.

# CHAPTER 3

## AIMS

The aims of the present study were as follows:-

(i) To determine the prevalence of persisting digit sucking habits amongst new patient referrals to the Orthodontic Department of a District General Hospital, with consideration given to the age and sex distribution of the cases.

(ii) To identify a subgroup of the persisting digit suckers for further investigation and to identify an appropriate control group of non digit suckers for comparison.

(iii) To describe the study group of digit suckers with respect to the modes of sucking, frequency of sucking and associated factors.

(iv) To compare the digit suckers with the controls with respect to a range of craniofacial morphology variables determined from lateral skull cephalometric radiographs. The cephalometric analysis would investigate vertical and anteroposterior variables of both a localised dental nature and a general skeletal nature, to identify any changes which could be attributed to digit sucking in the study group.

(v) To compare the digit suckers with the controls with respect to dental and occlusal characteristics determined from orthodontic study models. The variables investigated would assess the influence of digit sucking on the transverse dimension of the maxillary and mandibular dental arches, and also supplement the assessment of vertical and anteroposterior dimensions examined in the cephalometric analysis.

(vi) To subdivide the digit suckers under investigation according to identifiable characteristics of their habit, and thereby investigate whether any variables found to be influenced by the sucking habits are also dose related or related to mode of digit sucking.

(v) To investigate the hypothesis that persisting digit suckers attending the Orthodontic Department of a District General Hospital present with a higher orthodontic treatment need than is generally the case for non digit suckers, using an accepted index of orthodontic treatment need.

# CHAPTER 4

## SUBJECTS

A. Identification of persisting digit suckers.

The subjects for this study were drawn from the new patient consultation clinics in the Orthodontic Department of Victoria Hospital, Kirkcaldy. All patients were considered for the study who had initial consultation between 1-1-92 and 31-8-92, a period of 8 months.

The Orthodontic Department at Victoria Hospital provides a Consultant Orthodontic Service for Kirkcaldy and the surrounding East Fife district and accepts referrals from General Dental Practitioners, Community Dental Officers, other Hospital Dental Specialists and where appropriate from Hospital and General Medical Practitioners.

To fulfil the first aim of the study all new patients during the study period were assessed by the examining orthodontist as to whether they had a history of a persisting digit sucking habit. The age in years and sex of all patients falling into this category were recorded.

During the 8 month period a total of 885 new patient consultations were conducted at Victoria Hospital Orthodontic Department. Of these, 54 patients were found to have a history of a continuing digit sucking habit, which represents 6.1% of all new patient consultations.

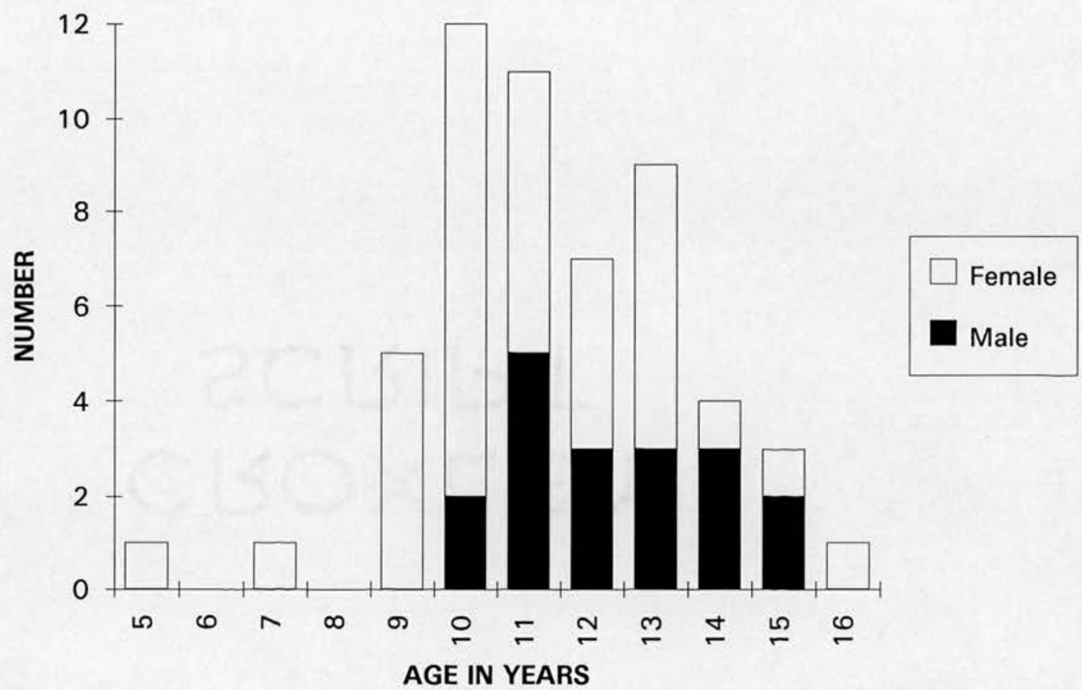
The age and sex distribution of the cases found to have a history of persisting digit sucking habit is illustrated in Figure 3. The mean age at the time of initial consultation was 11.4 years, with a range from 5 years to 16 years. 36 cases (66.7%) were female and 18 (33.3%) were male.

Normal practice in the department for treating patients with prolonged digit sucking habits involves an initial period of orthodontic aversion appliance therapy to help break the habit if it is considered to be causing orthodontic problems, and if the patient expresses a desire for treatment. This is carried out in conjunction with an explanation of the problem to the patient. Following cessation of the habit the occlusion is then reassessed and any necessary corrective orthodontic treatment provided.

In accordance with this practice the 54 patients were invited to return to the department for further assessment and commencement of aversion appliance therapy as clinically indicated. Four patients failed to attend for a further two appointments following their initial consultations. In common with department practice, these patients were discharged back to the care of their general dental practitioners and were not considered

Figure 3.

Age and sex distribution of the 54 subjects found to have a persisting digit sucking habit at their initial consultation.



further for this study. The age and sex distribution of the patients who failed to return to the department was as follows:- 1 female, 9 years; 1 male, 10 years; 1 male, 12 years and 1 male, 14 years.

B. Study Group

In order to concentrate the study on the subjects with the most persistent digit sucking habits and to minimise the possibility of problems related to poor co-operation among younger children, only those aged 10 years or older were considered for the study. Taking account of the patients who failed to attend after their initial consultation and of the age restriction mentioned, a total of 44 patients were invited to enter the study at their second visit to the department.

The nature of the study was explained to the patients and their parents and it was made clear that participation or otherwise in the study would not influence the treatment prescribed for their problem. It was explained that the study involved analysis of radiographs and study models taken as part of the normal treatment planning process, and that the only additional investigation would involve taking a detailed history of the sucking habit.

All 44 patients and their parents agreed to participate in the study. The age and sex distribution of the Study Group is detailed in Table 2. All patients in the Study Group were of British ancestry and were normally resident

Table 2.

Age and sex distribution of the Study Group.

| AGE | MALE | FEMALE | TOTAL |
|---|---|---|---|
| 10 | 1 | 10 | 11 |
| 11 | 5 | 6 | 11 |
| 12 | 2 | 4 | 6 |
| 13 | 3 | 6 | 9 |
| 14 | 2 | 1 | 3 |
| 15 | 2 | 1 | 3 |
| 16 | 0 | 1 | 1 |
| TOTAL | 15(34%) | 29(66%) | 44 (100%) |

in Kirkcaldy or the surrounding area of East Fife, Scotland. The Study Group can be considered to be a consecutive sample of patients over the age of 10 years, referred to the Orthodontic Department of Victoria Hospital Kirkcaldy and who were found to have persisting digit sucking habits.

C. Control Group

In order to fulfil several of the aims of the study a Control Group was identified for comparison with the Study Group.

The controls were drawn from new patient consultation clinics at Victoria Hospital Orthodontic Department using a stratified sampling method. The Control Group was stratified to have the same age and sex distribution as the Study Group to eliminate any bias that a different distribution may introduce. This was achieved by identifying cases of suitable age and sex from the clinic lists prior to the patients attending the department, with no knowledge as to the nature of their orthodontic problem and without reference to their letter of referral.

This sampling method continued until all age and sex strata were full, and the distribution of the Control Group matched that of the Study Group.

In view of the need to match the Control Group to the Study Group for age and sex, the period of collection of the Control Group continued for a longer period than that of the Study Group. The collection period for the Control Group was from 1-3-92 to 12-1-93.

Following their consultations, the patients thus selected were invited to act as controls in the study, and the nature of the study was explained. The only reasons for not including such a patient were if the patient declined or if they gave a history of a persisting digit sucking habit, or if a lateral skull cephalometric radiograph had not been considered necessary for their orthodontic assessment. One patient declined from taking part in the study, two patients randomly selected were found to have persisting digit sucking habits and one patient was eliminated from the control group as a cephalometric lateral skull radiograph had not been required for his orthodontic assessment.

Using the method described a Control Group of non digit sucking patients, stratified for age and sex to match the distribution of the Study Group was identified. All patients in the Control Group were of British ancestry and were normally resident in Kirkcaldy or the surrounding area of East Fife, Scotland. The Control Group can be considered to be a stratified sample of patients referred to the Orthodontic Department of Victoria Hospital Kirkcaldy, without persisting digit sucking habits and selected solely to match the age and sex distribution of the previously determined Study Group.

D. Ethical considerations.

In conducting research into health related issues, ethical considerations are clearly important. Prior to the active commencement of this study, the protocol for the proposed investigation was submitted to Dr. J. Horobin, Health Service Research Co-ordinator for Fife Health Board, and her advice taken regarding the ethics of the study. The study was considered to be ethical and appropriate in design. Since the study was an observational study of plaster study models and radiographs taken as part of the patients' routine management, involved no special tests or invasive measures purely for research purposes and did not involve any alteration to the treatment which patients would receive, Dr Horobin advised that the study would not require to be considered by the Fife Ethical Conduct Committee. However, throughout the study the research was conducted in accordance with the Declaration of Helsinki.

As already discussed, before any patient was included in the study, either as members of the Study Group or the Control Group, consent was obtained from their parents. In addition, full consent to investigate the patients was obtained from Mr. J. P. McDonald, the Consultant Orthodontist under whose care the patients were.

# CHAPTER 5

# METHODS

## A. History of the digit sucking habits.

### (i) Outline of the method.

Each patient in the Study Group was asked a number of questions to characterise their digit sucking habit. The history for this study was recorded at the patient's second visit to the department and the questions asked to a standardised manner in an attempt to minimise questioner bias. Responses were recorded in coded form on a patient data form along with a unique identifying number.

### (ii) History recorded.

Data was recorded for each member of the study group as follows.

1. Age in years at the last birthday.

2. Sex. 1=Male, 2=Female.

3. Which hand is the sucked digit on ?
   1=Left, 2=Right, 3=Variable.

4. Which digit is sucked ?
   1=Thumb, 2=Index, 3=Middle, 4=Ring, 5=Little,
   6=Multiple Fingers together, 7=Variable.

5. Which surface lies uppermost in the mouth?

   1=Dorsal, 2=Ventral, 3=Variable.

The answer to this question was determined by asking the subject to demonstrate their preferred mode of sucking.

6. Approximately how many hours a day is the digit present in the mouth?

All subjects were asked to make a judgement to the best of their ability in answering this question, and were asked to specify a duration in hours.

7. Are there any special times of the day or activities which are associated with the habit?

   0=None, 1=At school, 2=Watching television/reading, 3=When tired, 4=In bed, 5=Other (specify).

A condition for inclusion in the control group was the absence of any persisting digit sucking habit, and therefore the only history details recorded for this group were age and sex.

B. Cephalometric analysis of craniofacial morphology

(i) Outline of the method.

All patients in both the study group (N=44) and control group (N=44) had cephalometric lateral skull radiographs taken as part of their initial orthodontic assessment, and these radiographs were used for the cephalometric analysis of craniofacial morphological variables. A range of relevant anatomical landmarks were traced from each radiograph onto acetate tracing film. The tracings were then analysed using a computer based measurement system involving the digitisation of the anatomical landmarks from the acetate tracings. Testing of method error was undertaken and is detailed in Chapter 6.

(ii) Details of the radiographic procedures.

The radiographs used in this study were all taken in the Radiographic Department of Victoria Hospital, Kirkcaldy. All films were produced according to the departmental standardised protocol for cephalometric lateral skull radiographs, and were produced using the same Siemens Orthoceph 10S Cephalostat. Prior to taking films patients were instructed to remove all jewellery, hair clasps etc. from the head and neck region which may produce artefacts on the film. Patients wore a suitable lead apron and were positioned in the cephalostat in their natural erect stance, with the ear rods positioned just within the external auditory meatus. The nasal bridge marker was adjusted to contact the bridge of the nose and patients were instructed to bite together in their natural centric occlusion.

Fuji G8 high speed film and cassettes were used, size 18cm x 24cm. The film was positioned on the right side of the face, parallel to, and as close as possible to the mid-sagittal plane (i.e. touching the patient's face on the right side). The focal distance of 180cm and the focal spot size was 0.6mm. An aluminium wedge was used to selectively attenuate the beam to produce an image of the soft tissue profile on the same film as the hard tissue structures. Total filtration was 2.5mm aluminium and the exposure was set at 71 kV, 15 mA for 0.25 seconds. Film processing was by a Fuji Daylight Processor using Photosol Chemistry with a dry film to dry film time of 90 seconds.

The standard equipment and technique described were used for all films in the study to prevent problems of comparability most especially with respect to magnification errors. As a further check on such error all films were taken with a millimetre rule positioned in line with the patient's mid-sagittal plane, anterior to the frontal region. The image of the rule was used to check for uniformity of the magnification factor.

(iii) Method of tracing the radiographs.

In a darkened room the cephalometric lateral skull radiographs were fixed to a radiograph viewing box with adhesive tape and the surrounding area shielded with card to enable better landmark identification. A sheet of acetate tracing film was then firmly fixed to the radiograph with adhesive tape and a range of anatomical landmarks were traced using a sharp 4H pencil. The landmarks traced were those necessary to identify 35 specific points for digitisation and computer analysis as detailed below.

The tracings thus obtained were marked with the subject's name and unique identification number but no mark was made to indicate whether the tracing was of a study subject or a control subject.

(iv) Details of the computer based analysis of the tracings.

To measure a range of craniofacial variables from the cephalometric lateral skull tracings a computer based system was utilised. The hardware consisted of an IBM PS2 386 55SX personal computer, a Numonics 2210-1212 digitiser, a Hewlett Packard 7475A plotter, a Hewlett Packard Deskjet 500 printer and all necessary interface cables. The system is illustrated in Figure 4. Software consisted of MS DOS Version 3.30 together with a commercially available cephalometric analysis software programme, the "Dentofacial Planner", version 5.3.

Figure 4.

The computer system used in the cephalometric analysis. Individual components are, from the left, Numonics 2210-1212 Digitiser (standing on radiographic light box), Hewlett Packard 7475A Plotter, Hewlett Packard Deskjet 500 Printer and IBM PS2 386 personal computer.

The Dentofacial Planner has a range of manufacturer created digitising regimes which each consist of a sequence of anatomical landmarks. For the analysis in this study the "Short Lateral" digitising regime consisting of 35 cephalometric points was utilised as this included all the landmarks necessary for the desired measurements.

Figure 5 illustrates the Short Lateral digitising regime, with each point numbered in its digitising sequence. The names and definitions of each digitised point are detailed in Table 3.

Figure 5.

The "Short Lateral" digitising regime, as preprogrammed in the "Dentofacial Planner" cephalometric analysis programme.

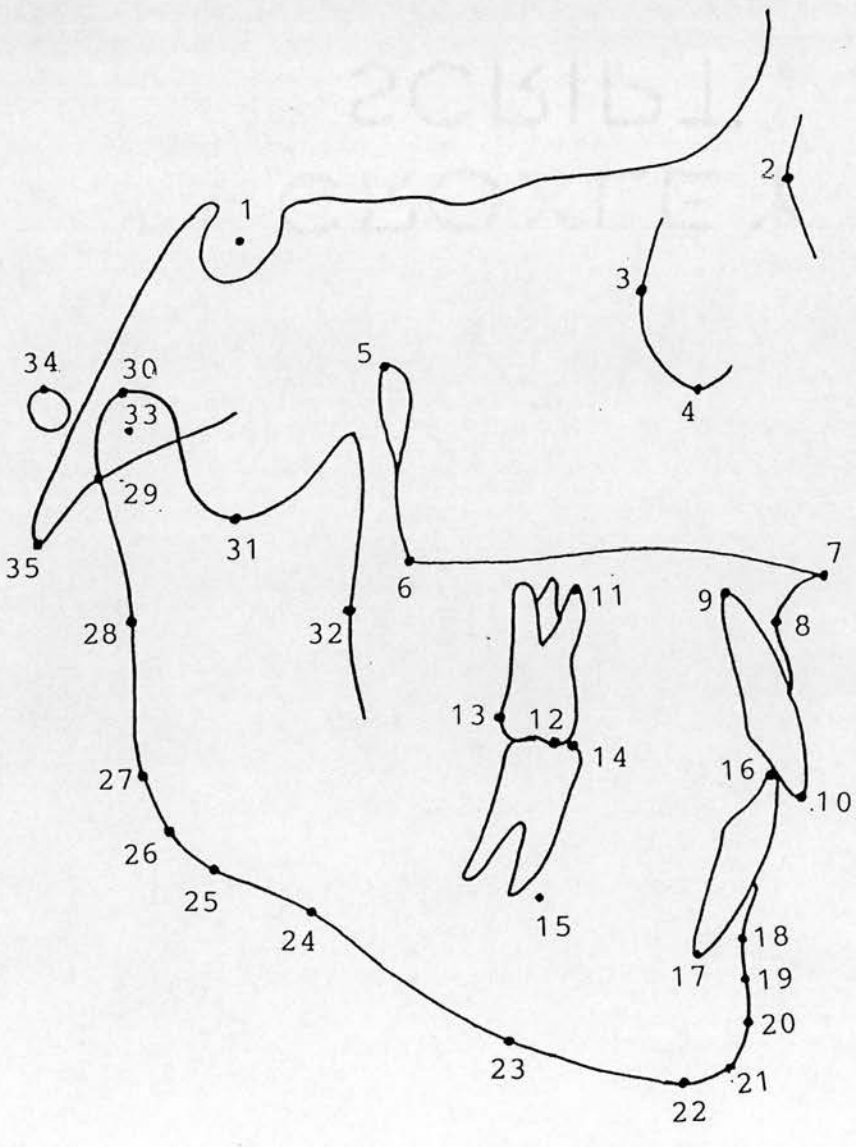


Table 3(i).

Names and definitions of anatomical landmarks digitised in the "Short Lateral" digitising regime, numbered in their digitising sequence.

| Number | Name and definition |
|---|---|
| 1. | Sella, the midpoint of the sella turcica. |
| 2. | Nasion, the most anterior point on the junction of the frontal and nasal bones at the naso-frontal suture. |
| 3. | Orbital Rim, the midpoint (supero-inferiorly) of the lateral orbital margin. |
| 4. | Orbitale, the most inferior point on the infra-orbital margin. |
| 5. | Pterygo-maxillary Fissure, at the eleven o'clock position of the contour of the pterygomaxillary fissure. |
| 6. | Pterygomaxillare, the posterior nasal spine where the nasal floor and the posterior contour of the maxilla intersect. |
| 7. | Spinal Point, the apex of the anterior nasal spine. |
| 8. | Subspinale (A point), the deepest point in the concavity of the anterior maxilla between the anterior nasal spine and the alveolar crest. |
| 9. | Apex Superius, the root apex of the most prominent upper central incisor. |

Table 3(ii).

Names and definitions of anatomical landmarks digitised in the "Short Lateral" digitising regime, numbered in their digitising sequence.

| Number | Name and definition |
|---|---|
| 10. | Incision Superius, the tip of the most prominent upper central incisor. |
| 11. | Upper Molar Apex, a point located on a perpendicular to the occlusal surface of the upper first molar through the mesial cusp tip. |
| 12. | Upper Molar Crown, the tip of the mesial cusp of the upper first molar. |
| 13. | Upper Molar Distal, a landmark located on the distal contact of the upper first molar. |
| 14. | Lower Molar Crown, the tip of the mesial cusp of the lower first molar. |
| 15. | Lower Molar Apex, a point located on a perpendicular to the occlusal surface of the lower first molar through the mesial cusp. |
| 16. | Incision Inferius , the tip of the of the most promiment lower central incisor. |
| 17. | Apex Inferius, the root apex of the most prominent lower central incisor. |
| 18. | Supramentale (B point) the deepest point of the concavity in the anterior mandible between the alveolar crest and Pogonion. |

Table 3(iii).

Names and definitions of anatomical landmarks digitised in the "Short Lateral" digitising regime, numbered in their digitising sequence.

| Number | Name and definition |
|---|---|
| 19. | Anterior Genioplasty Point, a point on the anterior chin contour midway between B Point and Pogonion. |
| 20. | Pogonion, the most anterior point of the bony chin. |
| 21. | Gnathion, the most antero-inferior point on the bony chin. |
| 22. | Menton, the most inferior point of the bony chin. |
| 23. | Posterior Genioplasty Point, a point on the lower border of the mandible representing the postero-inferior limit of a genioplasty osteotomy. |
| 24. | Antegonial, a point on the inferior border of the mandible at the depth of the antegonial notch. |
| 25. | Inferior gonion, a point at a tangent to the inferior border of the mandible near Gonion. |

Table 3(iv).

Names and definitions of anatomical landmarks digitised in the "Short Lateral" digitising regime, numbered in their digitising sequence.

| Number | Name and definition |
|---|---|
| 26. | Gonion, a point at the gonial angle of the mandible located where the bisector of the inferior and posterior mandibular border tangents meets the mandibular outline. |
| 27. | Posterior Gonion, a point at a tangent to the posterior border of the ramus near gonion. |
| 28. | Posterior ramus, a point on the posterior border of the mandibular ramus, approximately halfway between Articulare and Gonion. |
| 29. | Articulare, a point located at the intersection of the posterior border of the mandibular ramus and the inferior surface of the cranial base. |
| 30. | Condylion, the most postero-superior point of the mid-planed contour of the mandibular condyle. |
| 31. | Sigmoid, a landmark at the depth of the sigmoid notch of the mandible. |
| 32. | Anterior Ramus, a point located in the depth of the concavity of the anterior border of the ramus of the mandible. |

Table 3(v).

Names and definitions of anatomical landmarks digitised in the "Short Lateral" digitising regime, numbered in their digitising sequence.

| Number | Name and definition |
|---|---|
| 33. | Centre of Rotation, a landmark representing the centre of rotation of the mandible, arguably the centre of the head of the condyle. |
| 34. | Porion, the most superior point of the bony external auditory meatus. |
| 35. | Basion, the most inferior point on the anterior margin of foramen magnum. |

(v) Method of digitising tracings.

Each cephalometric tracing was fixed to the digitiser using adhesive tape. The active area of the digitiser was 307mm in the X axis and 255mm in the Y axis. Each acetate tracing of the 35 points measured 205mm in the X axis and 253 in the Y axis although the anatomical landmarks were confined to the central area of the acetate approximating to 140mm in the X axis and 165mm in the Y axis.

The tracings were positioned with the anterior landmarks to the right of the digitiser and the posterior landmarks to the left of the digitiser in accordance with the requirements of the Dentofacial Planner software. Care was taken to ensure that the region of the tracing bearing the anatomical landmarks was positioned as centrally as possible on the digitiser to minimise error due to lack of linearity of the digitiser as discussed in Chapter 6.

The patient unique identifying number was entered onto the Dentofacial Planner and the X and Y co-ordinate data was written to the computers memory by digitising the 35 points in the sequence detailed in Table 3 and illustrated in Figure 5. Once the full set of landmarks were digitised and the co-ordinate data saved, a 1:1 pen plot was created and compared with the tracing to check for gross digitising errors of either point placement or sequence. Any such errors were rectified by redigitising the tracing and rechecking in the same manner.

Once all tracings had been digitised the co-ordinate data for each case was analysed using a 19 variable analysis as described below. For each case a printout of results was created. Linear variables were quoted to 0.1mm and angular variables were quoted to 0.1 degrees.

(vi) Design of the 19 variable analysis.

In the Dentofacial Planner programme the "Tools" option allows for the creation of user-determined analyses. Linear dimensions and angles between lines created from both digitised and constructed landmarks may be specified. Using the Tools option an analysis was programmed specifically for this study, consisting of 11 angular and 8 linear dimensions, a total of 19 variables.

Each variable can be described in terms of the landmarks used and/or the reference lines passing through two landmarks. Angular measurements can be defined by the two reference lines which create the angle, or by a sequence of three anatomical landmarks which map out the angle. For the present analysis all the landmarks utilised were digitised (i.e. the computer did not construct any landmarks for the analysis.) Although 35 landmarks were digitised, only 17 of the landmarks were utilised in the present analysis. Table 4 list those points which were used, together with their digitising sequence number and short anatomical codes. Table 5 defines the 6 reference lines used. Figure 6 illustrates the 17 landmarks and 6 reference lines.

Table 4.

Anatomical landmarks used to create the cephalometric analysis.

| Digitising Sequence Number | Anatomical Name | Short Code |
|---|---|---|
| 17 | Apex Inferius. | ai |
| 9 | Apex Superius. | as |
| 35 | Basion. | ba |
| 30 | Condylion. | cd |
| 21 | Gnathion. | gn |
| 26 | Gonion. | go |
| 16 | Incision Inferius. | ii |
| 10 | Incision Superius. | is |
| 22 | Menton. | me |
| 2 | Nasion. | n |
| 4 | Orbitale. | or |
| 34 | Porion. | p |
| 6 | Pterygomaxillare. | pm |
| 1 | Sella. | s |
| 7 | Spinal Point. | sp |
| 18 | Supramentale (B Point). | sm |
| 8 | Subspinale (A Point). | ss |

Table 5.

Reference lines used in the cephalometric analysis.

| Code | Name | Landmarks through which the line passes. | |
|---|---|---|---|
| SNL | Sella-Nasion Line | s | n |
| $IL_s$ | Maxillary Incisor Line | as | is |
| $IL_i$ | Mandibular Incisor Line | ai | ii |
| MXP | Maxillary Plane | sp | pm |
| MNP | Mandibular Plane | me | go |
| FHP | Frankfort Horizontal Plane | or | p |

Figure 6.

Anatomical landmarks and reference lines used to create 19 variables in the cephalometric analysis. Explanation of the codes for landmarks and reference lines are listed in Tables 4 and 5 respectively.

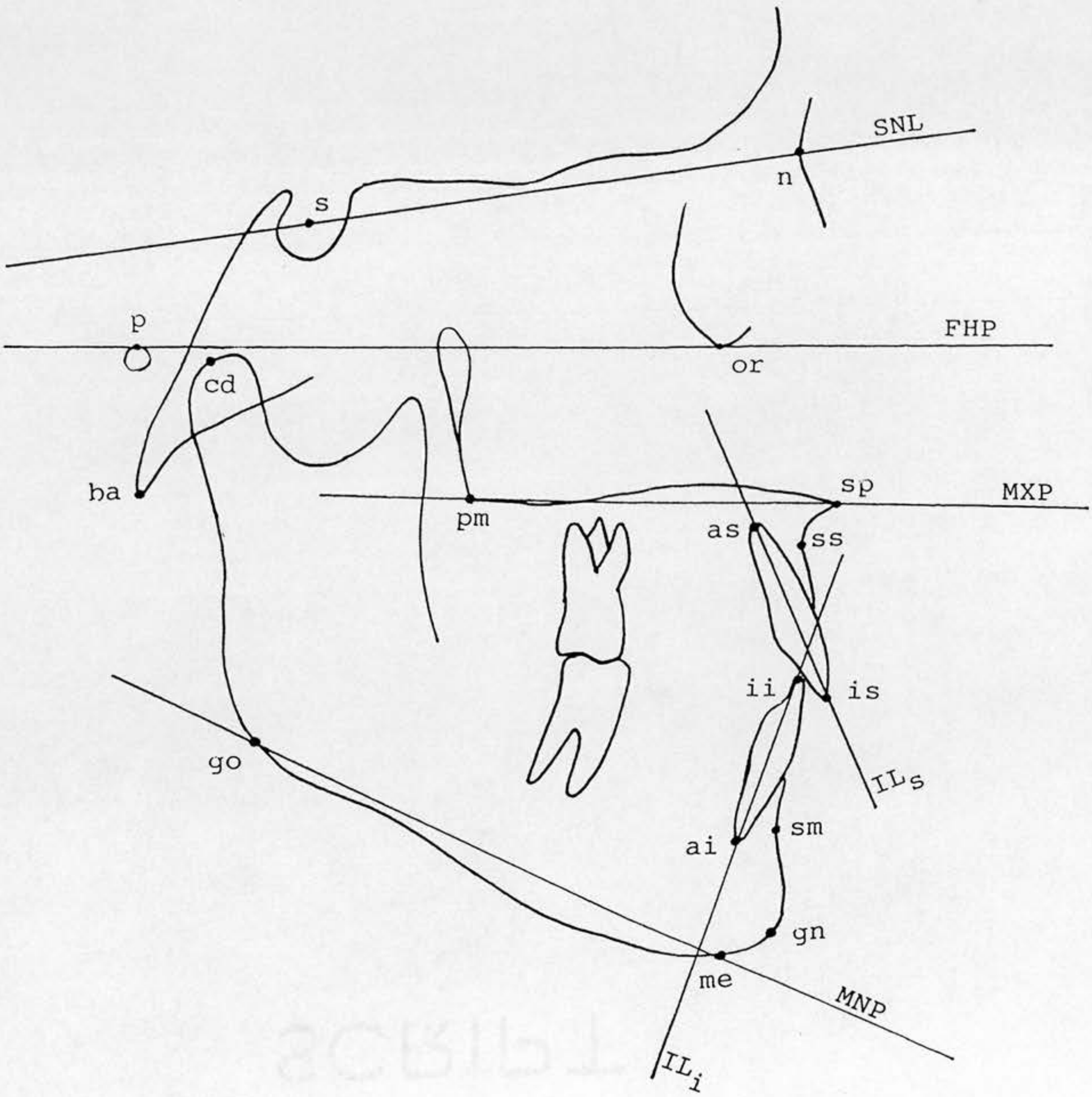


Table 6 lists the 11 angular variables which were measured in the cephalometric analysis, together with the landmarks or reference lines used to define them. Table 7 lists the 8 linear variables which were measured, together with the landmarks used to define them.

Three of the linear variables (numbers 14, 15 and 16 in Table 7) were defined as "vertical distances" rather than the true point to point distance. Clearly the orientation of the radiograph/tracing would influence such measurements. The Dentofacial Planner allows the operator to standardise the orientation of the radiograph for such measurements by choosing a reference line by which to orientate the digitised image. For this study the Frankfort Horiontal Plane, which passes through the digitised points Orbitale and Porion, was programmed as the horizontal reference line by which the Dentofacial Planner orientated the digitised image. No attempt to orientate the tracing on the digitiser with the Frankfort Horizontal Plane absolutely horizontal was necessary, as this manipulation was carried out in the computer's memory after the digitisation of all the points.

Table 6(i).

Angular variables determined by the cephalometric analysis.

Angles determined from three landmarks.

| | Landmarks | Description |
|---|---|---|
| 1. | s-n-ss | Maxillary prognathism, measured as the angle between sella, nasion and A point. |
| 2. | s-n-sm | Mandibular prognathism, measured as the angle between sella, nasion and B Point. |
| 3. | ss-n-sm | Relative prognathism, measured as the angle between A Point, Nasion and B Point. |
| 4. | ba-s-n | Cranial base angle, measured as the angle between basion, sella and nasion. |

Table 6(ii).

Angular variables determined by the cephalometric analysis.

Angles determined from two reference lines.

| | Reference Lines | Description |
|---|---|---|
| 5. | MXP-MNP | The angle between the maxillary plane and the mandibular plane. |
| 6. | $IL_s$-MXP | The angle between the maxillary incisor and the maxillary plane. |
| 7. | $IL_i$-MNP | The angle between the mandibular incisor and the mandibular plane. |
| 8. | $IL_i$-$IL_s$ | The inter-incisal angle. |
| 9. | $IL_s$-SNL | The angulation of the maxillary incisor relative to the anterior cranial base. |
| 10. | MXP-SNL | The angulation of the maxillary plane relative to the anterior cranial base. |
| 11. | MNP-SNL | The angulation of the mandibular plane relative to the anterior cranial base. |

Table 7.

Linear variables determined by the cephalometric analysis.

| Landmarks | Description |
|---|---|
| 12. pm-sp | Maxillary length, measured between the posterior nasal spine and the anterior nasal spine. |
| 13. cd-gn | Mandibular length, measured between condylion and gnathion. |
| 14. n-sp | Upper anterior facial height, measured as the vertical distance between nasion and the anterior nasal spine. |
| 15. sp-gn | Lower anterior facial height, measured as the vertical distance between the anterior nasal spine and gnathion. |
| 16. n-gn | Total anterior facial height, measured as the vertical distance between nasion and gnathion. |
| 17. s-pm | Posterior facial height, measured from sella to the posterior nasal spine. |
| 18. s-n | Anterior cranial base length, measured from sella to nasion. |
| 19. s-ba | Posterior cranial base length, measured from sella to basion. |

C. Dental and Occlusal analysis.

(i) Outline of the method.

Each subject in both the study group and the control group had alginate dental impressions taken using deep flanged stock trays, and an occlusal registration taken using softened modelling wax with the patient occluding in their natural position of maximum intercuspation. The impressions were cast in orthodontic stone and based and trimmed to correspond with the wax occlusal registration. The models were labelled with the patient's name and the date of the impression and were later used to determine a range of dental and occlusal variables.

(ii) Clinical methods.

All study models used in the study were produced in a uniform manner. Dental impressions were taken using Kromopan alginate impression material mixed in accordance with the manufacturer's instructions, and Dentaurum O-Tray deep flanged stock impression trays coated with a thin layer of Fix adhesive. Once taken, the impressions were rinsed to remove saliva deposits, gently shaken to remove excess water and were wrapped in a moistened gauze swab and a sealed polythene bag for transfer to the dental laboratory. A double thickness ( 3mm ) of dental modelling wax was softened in warm water and formed into a dental arch shape. The patient was instructed to bite right through the wax into their position of maximum intercuspation. The impressions were cast within the same working day and poured using a mechanical vibrator. Crystacal bases were applied and trimmed to correspond to the wax occlusal record and models were labelled with names and dates as appropriate. The occlusion of the models was checked against that of the patient at the following visit.

(iii) Dental and occlusal variables determined.

The variables determined in the study model analysis can be grouped as (a) those determined from the maxillary cast in isolation, (b) those determined from the mandibular cast in isolation and (c) those determined from both casts held in maximum intercuspation. In addition the Index of Orthodontic Treatment Need (IOTN) - Dental health Component (Brook and Shaw 1989) was assessed from the combined evidence provided by the study models. Variables determined from the study models are listed in Table 8.

(iv) Methods for determination of variables.

Those variables defined by a linear dimension were determined by direct measurement of the study models using fine point orthodontic callipers with Vernier gauge to the nearest 0.1mm, (except overjet and palatal vault depth which were determined to the nearest 0.5mm). Overbite, buccal crossbite and IOTN were recorded according to criteria as detailed below.

A single examiner technique was used to eliminate inter examiner variability. Intra examiner repeatability was tested and is reported in Chapter 6.

Table 8.

Variables determined from orthodontic study models.

| |
|---|
| Variables determined from maxillary cast alone |
| 1. Maxillary Intermolar Width. |
| 2. Maxillary Intercanine Width. |
| 3. Palatal Vault Depth. |
| Variables determined from mandibular cast alone. |
| 4. Mandibular Intermolar Width. |
| 5. Mandibular Intercanine Width. |
| Variables determined from both casts in occlusion. |
| 6. Incisor Overjet. |
| 7. Incisor Overbite. |
| 8. Buccal Segment Crossbites. |
| Variable determined from both casts generally. |
| 9. Index of Orthodontic Treatment Need. |

(v) Definitions and conventions used.

Maxillary Intermolar Width was defined as the distance between the mesiopalatal cusps of the maxillary first permanent molars.

Maxillary Intercanine Width was defined as the distance between the tips of the cusps of the maxillary permanent canine teeth.

Palatal Vault Depth was defined as the length of the perpendicular from the line joining the tips of the mesiopalatal cusps of the maxillary first permanent molars to the midline of the palate.

Mandibular Intermolar Width was defined as the distance between the mesiolingual cusps of the mandibular first permanent molars.

Mandibular Intercanine Width was defined as the distance between the tips of the cusps of the mandibular permanent canine teeth.

Intermolar and intercanine widths were not scored for cases found to have some of the defined teeth missing. If the permanent canine teeth were not present in the mouth, the deciduous canine teeth were not used as substitutes.

Incisor Overjet was defined as the maximum horizontal distance between the labial surfaces of the maxillary and mandibular central incisors. Where the maxillary central incisors had different labio-palatal positions, the incisor with the more labial position was used to determine the overjet.

Incisal Overbite was assessed from the position of the more inferiorly positioned maxillary central incisal edge relative to the mandibular central incisors. Overbite was scored on a scale of 1 to 6, with the criteria for each score as detailed below:-

1. Anterior open bite greater than 4mm, measured vertically between the incisal edges of the maxillary and mandibular incisors.

2. Anterior open bite greater than 2mm but less than or equal to 4mm.

3. Anterior open bite between 0mm (incisal edges level) and 2mm.

4. Positive overbite of up to 1/3 of the clinical crown length of the mandibular incisors. ( Includes normal overbite cases)

5. Positive overbite of between 1/3 and 2/3 of the clinical crown length of the mandibular incisors.

6. Positive overbite of greater than 2/3 of the clinical crown length of the mandibular incisors.

Buccal segment crossbites were scored as being present if two or more teeth on one side were in a crossbite situation of cusp to cusp relationship or worse. Models were classified as follows for buccal crossbite:-

1. No buccal crossbites present.
2. Unilateral crossbite, right side.
3. Unilateral crossbite, left side.
4. Bilateral crossbite.
5. Lingual crossbite, unilateral or bilateral.

The criteria for scoring the Index of Orthodontic Treatment Need - Dental Health Component were as laid down by Brook and Shaw (1989) and in accordance with the recommendations of the Basic Introductory Course in Occlusal Indices run by the University of Manchester. All cases were given a score between 1 and 5, scores 1 and 2 indicating little or no treatment need, 3 indicating moderate need for treatment and scores 4 and 5 indicating a definite treatment need.

D. Data collection and statistical analysis.

(i) Data Collection.

Each subject in the study was identified by a unique identifying number. All the data for each patient from the cephalometric and study model were transferred to a data form. In addition the Study Group had the results of the history enquiry recorded on the data form in coded form.

Accuracy of data transfer for the cephalometric assessment was checked at this stage by comparing each entry on the patient's data sheet with the printout obtained from the Dentofacial Planner and any necessary corrections made. Since the history data and study model data were recorded directly on to the data sheet, no checking for accuracy of data transfer was required at this stage for these variables.

The data collected was analysed using the "Epi Info" computerised statistical analysis package, designed by the World Health Organisation in conjunction with the Centre for Disease Control, for statistical analysis in health related research.

The collected data for each subject was transferred to computer disk file using the "Data Entry" facility of Epi Info. Data transfer was checked by checking a printout of all data which had been entered with the original data sheets and also by using the data checking facility of Epi Info to check that each item of data was within it's logical range. Any data transfer errors were corrected at this stage.

(ii) Data Analysis.

Data analysis was conducted in three stages. Firstly a descriptive analysis of the historical data on the nature of the digit sucking habits was conducted for the study group alone. Secondly statistical comparisons were made between the Study and Control Groups with respect to the data from the cephalometric and study model assessments. Thirdly, intra-group statistical comparisons were made for historical, cephalometric and study model variables between subgroups of the total Study Group, the subgroups being identified by characteristics determined from the historical data collected.

# CHAPTER 6

## METHOD ERROR TESTING

### A. Introduction

With any measurement system errors are bound to occur and for results to have validity, an assessment of the degree of error inherent in the system is necessary. Consideration of method error for each of the methods undertaken was made and is detailed in this chapter.

### B. Cephalometric Analysis

Sources of error in measurement from cephalometric radiographs have been categorised by Houston et al (1986) as occurring at three stages :- (i) Errors introduced in taking the radiograph (ii) Tracing and landmark identification errors and (iii) Machine errors where computer aided measurements are used.

#### (i) Radiographic error

To comprehensively analyse the degree of error introduced in taking the radiographs used in this study would have necessitated subjecting patients to repeat exposure to X-rays, a practice which was considered to be inappropriate in the circumstances. However, in an attempt to minimise such errors all films were taken in the same department, using the same X-ray machine and cephalostat and by fully trained radiographers experienced in the technique. In accordance with Departmental practice all radiographs were scrutinised for adequate hard and soft tissue landmarks and checked for a correct centric occlusion of the dentition. No films required to be rejected at this stage.

To assess the degree of magnification for each cephalometric radiograph, all films were taken with a 40mm rule positioned anterior to the patient's forehead, in the mid-sagittal plane. The image of the rule on the films was measured to the nearest 1mm using a steel orthodontic calliper and a percentage magnification factor calculated for each film. The study group (n=44) was found to have a mean magnification factor of 8.85%, with a standard deviation of 1.97. The control group was found to have a mean magnification factor of 8.72%, with a standard deviation of 2.19. A two sample t-test revealed no statistically significant difference in the level of magnification for the study and control groups.( P>0.50 )

Houston et al (1986) investigated the relative importance of the errors in cephalometric analysis and in agreement with Mitgard et al (1974) and Ahlqvist et al (1986) found that errors arising in obtaining the radiographs are small provided due care is given to patient positioning. Having addressed the issue of magnification there is no reason to believe that the radiographs used in this study have an unusually high level of error due to the radiographic technique.

(ii) Digitisation error.

The computer aided analysis which was carried out as described in Chapter 5 involved digitising tracings of lateral skull cephalometric radiographs. Error may be introduced at two levels in this procedure, namely error in reproducibility of single points by the digitiser and the operator and errors due to distortion of the linearity of the active field of the digitiser.

(a) Single point reproducibility.

The single point reproducibility of the digitiser relates to the precision with which a marked point on a film or tracing can be identified by the cross hairs of the digitiser cursor together with the resolution and machine errors of the digitising system.

To assess the single point reproducibility of the system, a printout of an ideal tracing, with finely identified points indicated, was fixed to the central area of the digitising tablet with adhesive tape. Twenty-five points were digitised, and the X and Y co-ordinates were recorded to the nearest 0.1mm, these figures being displayed by the computer after the digitisation of each point. The points were then redigitised without moving the printout, and the co-ordinates recorded. The difference in X and Y co-ordinates for the two digitisations were calculated by subtracting the second reading from the first.

Bland (1987) states that the best estimate of the method error statistic (s) is given by the formula:-

$$s = \sqrt{\frac{1}{2\,n} \sum (x_i - y_i)^2}$$

Where $x_i$ and $y_i$ are the pairs of repeat measurement for $i = 1$ to $n$.

Tables 9 and 10 show the recordings for the X and Y co-ordinates, the differences between the two readings the mean difference per reading and the calculation of "s" for each.

The British Standards Institution (1979) recommends that measurement error should be quoted as the value below which the difference between two measurements will lie with probability 0.95. This is calculated by the following formula for data with normal distribution:-

$$95\% \text{ limit} = 1.96 \times \sqrt{(2\,s^2)}$$

The 95% confidence limit for the error in single point reproducibility are given on Table 9 and Table 10 for the X and Y co-ordinates respectively.

Considering the X co-ordinate, the mean error of 0.02mm was very small and indicates that there was little tendency for either the first or second reading to be consistently larger. The method error value "s" being 0.063mm and the 95% confidence limit for error being 0.18mm indicate that the error is very small and is of negligible clinical significance.

Table 9.

Single point reproducibility test. First and second readings for digitised X co-ordinates.

| Point | First reading | Second reading | Difference |
|---|---|---|---|
| 1 | 98.6 | 98.7 | -0.1 |
| 2 | 169.6 | 169.5 | 0.1 |
| 3 | 151.5 | 151.5 | 0.0 |
| 4 | 158.4 | 158.3 | 0.1 |
| 5 | 118.3 | 118.4 | -0.1 |
| 6 | 122.0 | 122.0 | 0.0 |
| 7 | 174.0 | 174.1 | -0.1 |
| 8 | 169.6 | 169.6 | 0.0 |
| 9 | 163.5 | 163.4 | 0.1 |
| 10 | 173.1 | 173.1 | 0.0 |
| 11 | 143.8 | 143.7 | 0.1 |
| 12 | 141.6 | 141.7 | -0.1 |
| 13 | 134.3 | 134.2 | 0.1 |
| 14 | 143.9 | 143.8 | 0.1 |
| 15 | 141.7 | 141.5 | 0.2 |
| 16 | 170.9 | 170.9 | 0.0 |
| 17 | 162.1 | 162.0 | 0.1 |
| 18 | 167.5 | 167.6 | -0.1 |
| 19 | 168.1 | 168.1 | 0.0 |
| 20 | 168.6 | 168.7 | -0.1 |
| 21 | 166.3 | 166.2 | 0.1 |
| 22 | 161.3 | 161.4 | -0.1 |
| 23 | 133.4 | 133.4 | 0.0 |
| 24 | 110.1 | 110.0 | 0.1 |
| 25 | 101.8 | 101.8 | 0.0 |

Mean difference = 0.02mm

Method Error (s) = 0.063mm

95% confidence limit = 0.18mm

Table 10.

Single point reproducibility test. First and second readings for digitised Y co-ordinates.

| Point | First reading | Second Reading | Difference |
|---|---|---|---|
| 1 | 175.5 | 175.3 | 0.2 |
| 2 | 184.8 | 184.8 | 0.0 |
| 3 | 172.5 | 172.4 | 0.1 |
| 4 | 157.6 | 157.5 | 0.1 |
| 5 | 159.2 | 159.2 | 0.0 |
| 6 | 133.9 | 133.9 | 0.0 |
| 7 | 132.9 | 132.9 | 0.0 |
| 8 | 127.6 | 127.5 | 0.1 |
| 9 | 130.6 | 130.5 | 0.1 |
| 10 | 105.0 | 104.9 | 0.1 |
| 11 | 131.1 | 131.1 | 0.0 |
| 12 | 110.8 | 110.8 | 0.0 |
| 13 | 114.5 | 114.5 | 0.0 |
| 14 | 111.2 | 111.2 | 0.0 |
| 15 | 90.9 | 90.8 | 0.1 |
| 16 | 106.9 | 107.1 | -0.2 |
| 17 | 83.7 | 83.7 | 0.0 |
| 18 | 84.7 | 84.7 | 0.0 |
| 19 | 79.4 | 79.4 | 0.0 |
| 20 | 74.2 | 74.2 | 0.0 |
| 21 | 69.5 | 69.4 | 0.1 |
| 22 | 66.6 | 66.7 | -0.1 |
| 23 | 74.0 | 74.1 | -0.1 |
| 24 | 89.3 | 89.4 | -0.1 |
| 25 | 92.5 | 92.4 | 0.1 |

Mean difference = 0.01mm

Method Error (s) = 0.062mm

95% confidence limit = 0.17mm

For the Y co-ordinate the mean error of 0.01mm also demonstrates no tendency for either the first or the second reading to be consistently larger. The value of "s" for the Y co-ordinate was 0.062mm and the 95% confidence limit was 0.17mm, again indicating that this source of error was of negligible clinical significance.

(b) Linearity of the digitiser.

Erikson and Solow (1991) have pointed out that if a digitising system is not linear, a given line will be recorded as having a different length depending on where it is placed on the digitising surface. In an attempt to assess and minimise such error in this study the following test was carried out.

The active area of the digitiser was marked out by recording points progressively further away from the centre. The Dentofacial Planner utilises the upper 50mm of the digitiser to send specific messages to the computer and this area is not available for digitising cephalometric points. The final active area thus located was found to be 307mm in the X axis and 255mm in the Y axis, and the position of this area was marked on the digitising surface with a fine felt-tip pen.

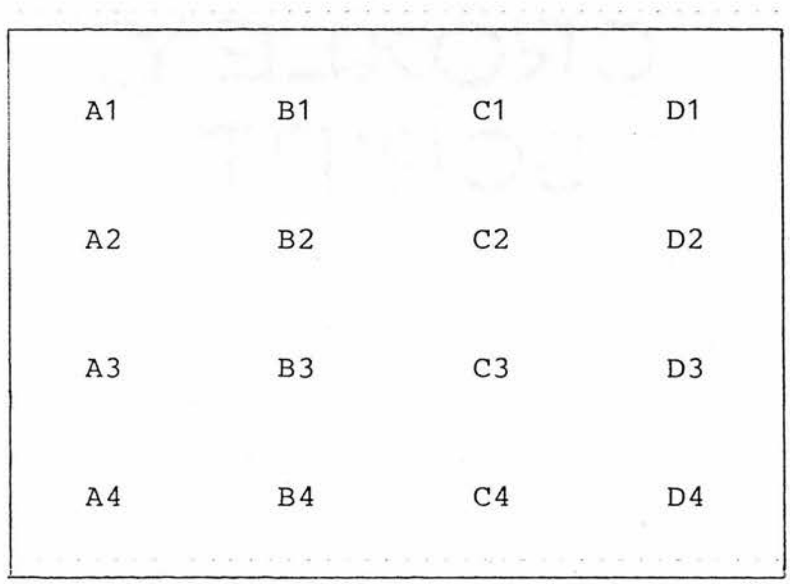
An ideal cephalometric template with 35 finely identified cephalometric landmarks was then digitised in 16 different positions on the active area, each time with the template firmly positioned on the digitiser with adhesive tape.

The 16 loci were determined in a systematic manner in 4 rows (numbered 1-4) and 4 columns (A-D). Row 1 was positioned with the most superior landmark 10mm within the active area at the top of the digitiser, and Row 4 was positioned with the most inferior landmark 10mm within the active area at the base of the digitiser. Rows 3 and 4 were positioned in the intervening space with all rows equally spaced. The vertical displacement between rows was 40mm. In a similar manner the columns were located, Column A being located with the most posterior landmark 10mm within the active area on the left margin, and Column D being located with the most anterior landmark 10mm within the active area on the right. Columns B and C were positioned in the intervening space and all columns were equally spaced. The horizontal displacement between columns was 65mm.

Using this technique the 16 loci were identified as "A1" to "D4", and the entire active area was utilised. Figure 7 illustrates schematically the relative positions of the template on the digitiser for each recording. The size of the template relative to the digitiser surface resulted in some overlap between adjacent loci.

Figure 7.

Schematic plan showing the relative positions of the template on the digitiser for each recording, and the identifying code for each.



From the digitised cephalometric landmarks 10 arbitrary linear dimensions were identified, and these are illustrated in Figure 8. The "true length" of each line was measured from the template, to the nearest 0.1mm, using fine point orthodontic callipers with Vernier scale. The callipers are illustrated in Figure 9.

Using the Dentofacial Planner "Tools" option an analysis consisting of the same 10 linear measurements was programmed. For each of the 16 loci in which the template had been digitised, a printout of the 10 linear measurements as determined by the Dentofacial Planner was output.

Figure 8.

Illustration of the 10 linear dimensions measured in the assessment of error resulting from lack of linearity of the digitiser.

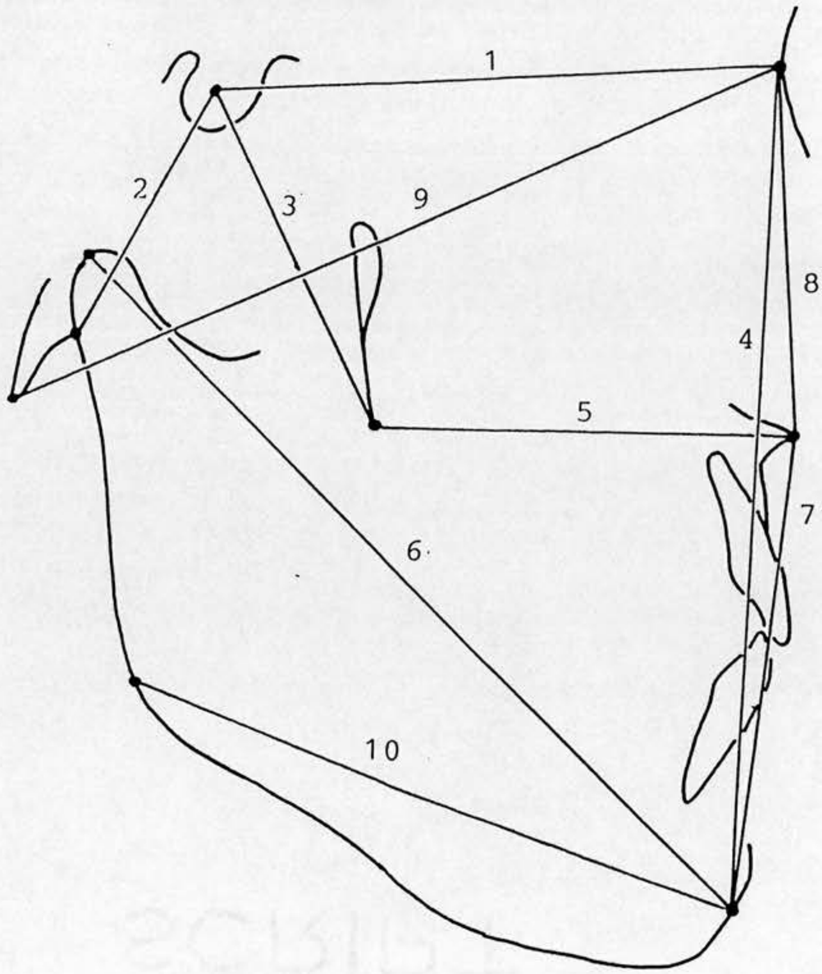
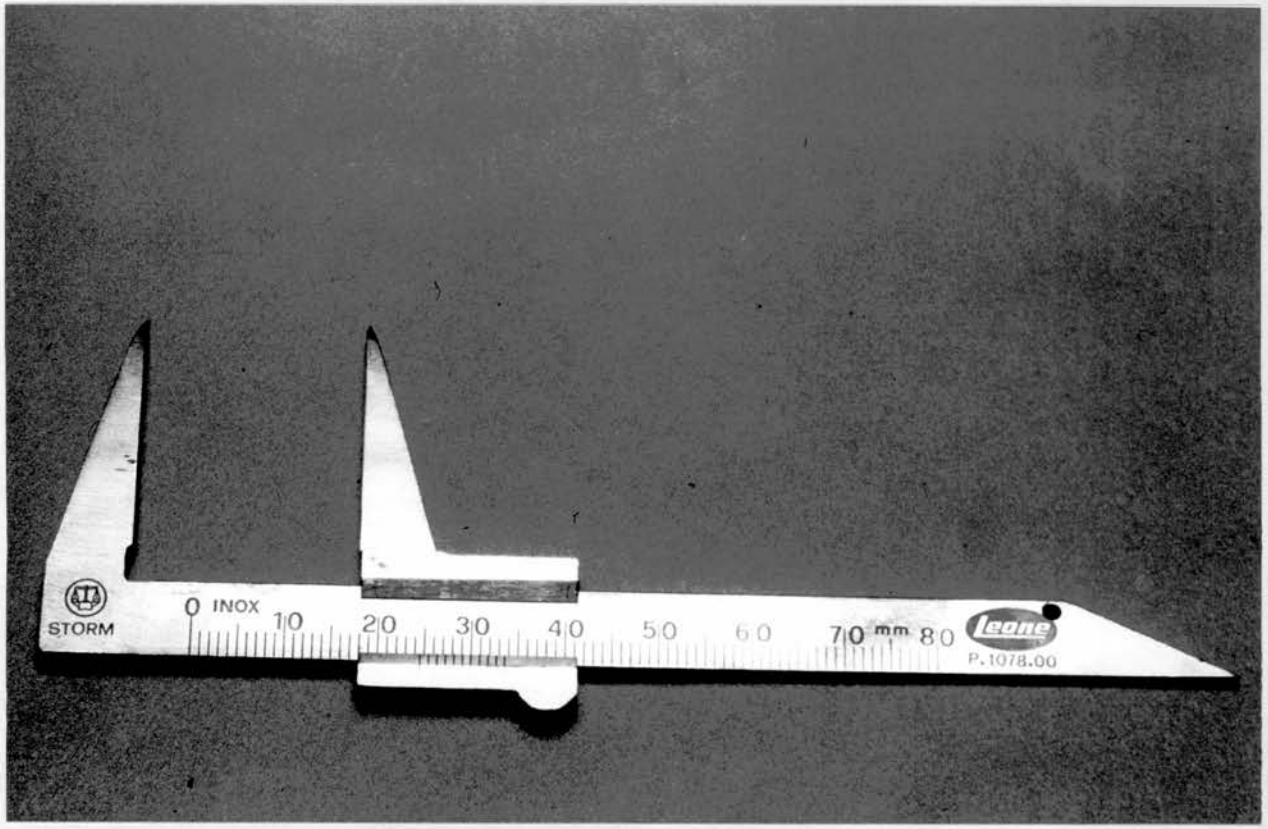


Figure 9.

Fine point orthodontic callipers with Vernier scale.



Linear distortion error was assessed in two stages to first identify the region on the digitiser where least error occurred and then to quantify the method error for that region.

Assessment of region with least linearity error.
The "error" of each measurement determined from digitised data was calculated as the deviation away from the true measurement, to the nearest 0.1mm. All errors were given a positive sign irrespective of whether they represented readings higher or lower than the true length. For each position in which the template was digitised, the total amount of error was the sum of the errors of each measurement.

Table 11 details the results of the linearity error test. Considering all 160 linear measurements 90% were within 0.5mm of the true length. The most extreme single error was 1.1mm for line 5 in position D4. The median error was 0.2mm.

Figure 10 illustrates in three dimensions the results in terms of the total amount of measurement error for each position in which the template was digitised. It can be seen that total amounts of error were smallest when the template was positioned in the more central area of the digitiser ( positions B2, C2, B3 and C3) and highest when the template was positioned in the peripheral area of the digitiser.

Table 11(i).

Results of the linearity error test. Measured lengths and error for lines 1 to 10 after digitisation in positions A1, B1, C1 and D1.

| Line | True Length | Measured Lengths (Error) in mm. | | | |
|---|---|---|---|---|---|
| | | A1 | B1 | C1 | D1 |
| 1 | 71.9 | 72.3(0.4) | 72.1(0.2) | 71.5(0.4) | 71.2(0.7) |
| 2 | 35.2 | 35.0(0.2) | 35.1(0.1) | 35.2(0.0) | 35.2(0.0) |
| 3 | 47.8 | 48.1(0.3) | 47.8(0.0) | 47.6(0.2) | 47.7(0.1) |
| 4 | 116.0 | 115.6(0.4) | 115.7(0.3) | 115.6(0.4) | 115.4(0.6) |
| 5 | 52.1 | 52.1(0.0) | 52.2(0.1) | 52.2(0.1) | 51.4(0.7) |
| 6 | 118.9 | 119.0(0.1) | 118.9(0.0) | 118.8(0.1) | 118.4(0.5) |
| 7 | 64.0 | 63.6(0.4) | 63.7(0.3) | 63.7(0.3) | 63.7(0.3) |
| 8 | 52.5 | 52.0(0.5) | 52.0(0.5) | 51.9(0.6) | 51.7(0.8) |
| 9 | 107.3 | 106.9(0.4) | 107.3(0.0) | 107.1(0.2) | 106.7(0.6) |
| 10 | 78.4 | 78.9(0.5) | 78.6(0.2) | 78.2(0.2) | 77.8(0.6) |
| TOTAL ERROR | | 3.2mm | 1.7mm | 2.5mm | 4.9mm |

Table 11(ii).

Results of the linearity error test. Measured lengths and error for lines 1 to 10 after digitisation in positions A2, B2, C2 and D2.

| Line | True Length | Measured Lengths (Error) in mm. | | | |
|---|---|---|---|---|---|
| | | A2 | B2 | C2 | D2 |
| 1 | 71.9 | 72.1(0.2) | 71.8(0.1) | 71.7(0.2) | 71.5(0.4) |
| 2 | 35.2 | 35.0(0.2) | 35.1(0.1) | 35.1(0.1) | 35.1(0.1) |
| 3 | 47.8 | 48.2(0.4) | 48.0(0.2) | 47.9(0.1) | 47.7(0.1) |
| 4 | 116.0 | 115.9(0.1) | 116.0(0.0) | 115.9(0.1) | 115.8(0.2) |
| 5 | 52.1 | 52.0(0.1) | 52.1(0.0) | 52.0(0.1) | 51.7(0.4) |
| 6 | 118.9 | 119.0(0.1) | 118.8(0.1) | 118.9(0.0) | 118.6(0.3) |
| 7 | 64.0 | 63.6(0.4) | 63.7(0.3) | 63.5(0.5) | 63.5(0.5) |
| 8 | 52.5 | 52.3(0.2) | 52.3(0.2) | 52.4(0.1) | 52.2(0.3) |
| 9 | 107.3 | 107.0(0.3) | 107.5(0.2) | 107.5(0.2) | 107.2(0.1) |
| 10 | 78.4 | 78.7(0.3) | 78.3(0.1) | 78.3(0.1) | 77.9(0.5) |
| TOTAL ERROR | | 2.3mm | 1.3mm | 1.5mm | 2.9mm |

Table 11(iii).

Results of the linearity error test. Measured lengths and error for lines 1 to 10 after digitisation in positions A3, B3, C3 and D3.

| Line | True Length | Measured Lengths (Error) in mm. | | | |
|---|---|---|---|---|---|
| | | A3 | B3 | C3 | D3 |
| 1 | 71.9 | 72.5(0.6) | 72.2(0.3) | 71.9(0.0) | 71.5(0.4) |
| 2 | 35.2 | 34.7(0.5) | 35.1(0.1) | 35.2(0.0) | 35.3(0.1) |
| 3 | 47.8 | 47.9(0.1) | 47.6(0.2) | 47.6(0.2) | 47.7(0.1) |
| 4 | 116.0 | 115.8(0.2) | 115.9(0.1) | 115.8(0.2) | 116.0(0.0) |
| 5 | 52.1 | 52.1(0.0) | 52.2(0.1) | 52.2(0.1) | 51.8(0.3) |
| 6 | 118.9 | 118.9(0.0) | 118.8(0.1) | 118.8(0.1) | 118.5(0.4) |
| 7 | 64.0 | 63.5(0.5) | 63.7(0.3) | 63.6(0.4) | 63.5(0.5) |
| 8 | 52.5 | 52.3(0.2) | 52.2(0.3) | 52.2(0.3) | 52.4(0.1) |
| 9 | 107.3 | 106.8(0.5) | 107.3(0.0) | 107.4(0.1) | 107.3(0.0) |
| 10 | 78.4 | 78.6(0.2) | 78.3(0.1) | 78.3(0.1) | 78.0(0.4) |
| TOTAL ERROR | | 2.8mm | 1.6mm | 1.5mm | 2.3mm |

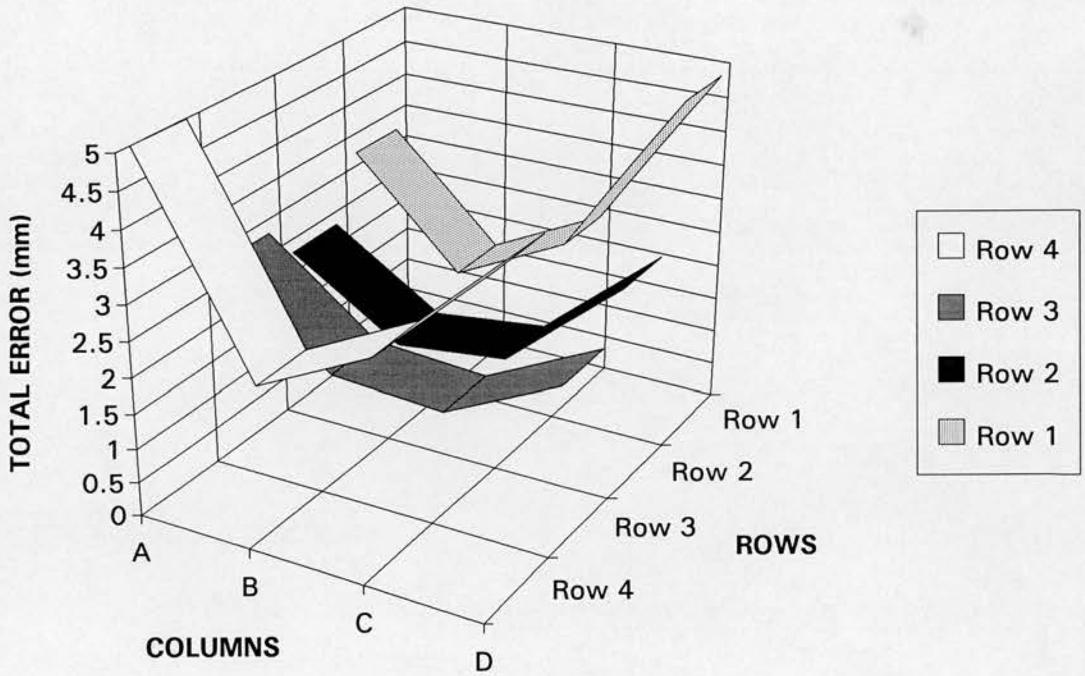
Table 11(iv).

Results of the linearity error test. Measured lengths and error for lines 1 to 10 after digitisation in positions A4, B4, C4 and D4.

| Line | True Length | Measured Lengths (Error) in mm. | | | |
|---|---|---|---|---|---|
| | | A4 | B4 | C4 | D4 |
| 1 | 71.9 | 72.6(0.7) | 71.8(0.1) | 71.8(0.1) | 71.4(0.5) |
| 2 | 35.2 | 34.6(0.6) | 35.3(0.1) | 35.0(0.2) | 35.2(0.0) |
| 3 | 47.8 | 48.0(0.2) | 48.1(0.3) | 47.6(0.2) | 47.9(0.1) |
| 4 | 116.0 | 115.2(0.8) | 116.0(0.0) | 115.6(0.4) | 115.8(0.2) |
| 5 | 52.1 | 52.0(0.1) | 51.6(0.5) | 52.0(0.1) | 51.0(1.1) |
| 6 | 118.9 | 118.2(0.7) | 119.1(0.2) | 118.5(0.4) | 118.4(0.5) |
| 7 | 64.0 | 63.1(0.9) | 63.9(0.1) | 63.1(0.9) | 63.5(0.5) |
| 8 | 52.5 | 52.1(0.4) | 52.1(0.4) | 52.4(0.1) | 52.3(0.2) |
| 9 | 107.3 | 106.9(0.4) | 107.5(0.2) | 107.2(0.1) | 106.9(0.4) |
| 10 | 78.4 | 78.2(0.2) | 78.1(0.3) | 77.9(0.5) | 77.4(1.0) |
| TOTAL ERROR | | 5.0mm | 2.2mm | 3.0mm | 4.5mm |

Figure 10.

Three dimensional representation of the total error in the measurement of 10 linear dimensions in each of 16 loci on the digitiser surface.



Method error for linearity - central region of digitiser.

Having established that errors were smallest within the central region of the digitiser the method error in this region was then quantified. The linear dimensions obtained with the template in positions B2, C2, B3 and C3 were used for this stage.

With four sets of dimensions, a total of six pairs were possible.(B2-C2, B2-B3, B2-C3, C2-B3, C2-C3, B3-C3) The differences between each measurement were calculated, and from these the method error value (s) was calculated. Table 12 lists the differences in linear measurement for each line, for each pair of positions.

When all possible paired measurements were considered, the method error value was 0.12mm, and the 95% confidence limit was 0.33mm. This represents the combined total error of linearity and twice the error for single point reproducibility since two points were digitised for each line measured.

Table 12.

Differences in the measurement of lines 1 to 10 for each pair of positions in which the template was digitised. (in mm)

| | PAIRED READINGS | | | | | |
|---|---|---|---|---|---|---|
| Line | B2-B3 | B2-C2 | B2-C3 | C2-B3 | C2-C3 | B3-C3 |
| 1 | -0.4 | 0.1 | -0.1 | -0.5 | -0.2 | 0.3 |
| 2 | 0.0 | 0.0 | -0.1 | 0.0 | -0.1 | -0.1 |
| 3 | 0.4 | 0.1 | 0.4 | 0.3 | 0.3 | 0.0 |
| 4 | 0.1 | 0.1 | 0.2 | 0.0 | 0.1 | 0.1 |
| 5 | -0.1 | 0.1 | -0.1 | -0.2 | -0.2 | 0.0 |
| 6 | 0.0 | -0.1 | 0.0 | 0.1 | 0.1 | 0.0 |
| 7 | 0.0 | 0.2 | 0.1 | -0.2 | -0.1 | 0.1 |
| 8 | 0.1 | -0.1 | 0.1 | 0.2 | 0.2 | 0.0 |
| 9 | 0.2 | 0.0 | 0.1 | 0.2 | 0.1 | -0.1 |
| 10 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Mean difference = 0.03mm

Method Error (s) = 0.12mm

95% confidence limit = 0.33mm

(iii) Total error for cephalometric variables.

To assess the total error for each of the cephalometric variables a repeat assessment test was conducted following the same method used for the formal part of the study.

Twelve lateral skull cephalograms were selected at random from the control group for the duplicate assessment. The radiographs were traced and subsequently digitised following the method described in Chapter 5. Printouts of the cephalometric variables were produced for each case, and in addition a 1:1 plot was produced and compared with each cephalogram to check for gross digitisation errors. One case required to be redigitised at this stage because of an error in digitisation sequence. Two weeks later the entire process was repeated using the same radiographs without reference to the initial tracings or results.

Through the adoption of single examiner technique inter-examiner variation was eliminated. The two week gap between tracings was adopted to prevent memory of landmark identification to bias the results.

For the nineteen cephalometric variables, the difference between first and second readings for the twelve cases was calculated. The mean difference, standard deviation and method error (s) was calculated for each variable together with the 95% confidence limit for error as recommended by the British Standards Institution (1979) and these figures are listed in Table 13.

Table 13(i).

Calculation of total method error for each angular cephalometric variable as determined by the duplicated assessment of 12 cases. "Error" quoted is defined as the difference between the first and second measured values for each variable. Angular errors are quoted in degrees.

| Variable | Error range | Mean Error | Error Standard Deviation | Method Error (s) | 95% Conf. Limit |
|---|---|---|---|---|---|
| 1. s-n-ss | +1.1 to -1.7 | -0.12 | 0.786 | 0.540 | 1.50° |
| 2. s-n-sm | +0.8 to -0.7 | -0.10 | 0.424 | 0.296 | 0.82° |
| 3. ss-n-sm | +0.5 to -1.0 | -0.02 | 0.486 | 0.326 | 0.91° |
| 4. ba-s-n | +1.7 to -1.0 | 0.17 | 0.807 | 0.559 | 1.55° |
| 5. MXP-MNP | +1.3 to -2.2 | 0.02 | 0.954 | 0.646 | 1.79° |
| 6. $IL_s$-MXP | +0.6 to -3.0 | -0.94 | 1.133 | 1.016 | 2.82° |
| 7. $IL_i$-MNP | +2.3 to -2.5 | 0.12 | 1.513 | 1.027 | 2.85° |
| 8. $IL_i$-$IL_s$ | +2.9 to -4.1 | 0.09 | 2.220 | 1.505 | 4.17° |
| 9. $IL_s$-SNL | +4.0 to -2.3 | -0.22 | 1.652 | 1.129 | 3.13° |
| 10.MXP-SNL | +0.5 to -1.1 | -0.16 | 0.480 | 0.343 | 0.95° |
| 11.MNP-SNL | +1.7 to -1.9 | -0.12 | 0.979 | 0.668 | 1.85° |

Table 13(ii).

Calculation of total method error for each linear cephalometric variable as determined by the duplicated assessment of 12 cases. "Error" quoted is defined as the difference between the first and second measured values for each variable. Linear errors are quoted in mm.

| Variable | Error range | **Mean Error** | Error Standard Deviation | **Method Error (s)** | 95% Conf. Limit |
|---|---|---|---|---|---|
| 12. **pm-sp** | +1.2 to -1.3 | **-0.08** | 0.814 | **0.555** | 1.54mm |
| 13. **cd-gn** | +0.5 to -2.0 | **-0.25** | 0.767 | **0.548** | 1.52mm |
| 14. **n-sp** | +0.9 to -1.3 | **0.02** | 0.578 | **0.392** | 1.09mm |
| 15. **sp-gn** | +1.3 to -1.0 | **0.07** | 0.748 | **0.508** | 1.41mm |
| 16. **n-gn** | +1.8 to -1.6 | **0.08** | 0.972 | **0.661** | 1.83mm |
| 17. **s-pm** | +0.7 to -0.5 | **0.07** | 0.345 | **0.236** | 0.66mm |
| 18. **s-n** | +0.7 to -0.8 | **0.02** | 0.409 | **0.277** | 0.77mm |
| 19. **s-ba** | +0.9 to -0.6 | **0.01** | 0.532 | **0.360** | 1.00mm |

The findings of the total method error test combine the effects of landmark identification error, digitiser linearity error and error attributable to the single point reproducibility of the digitising system. The latter two components have already been demonstrated to be small and so by far the most significant factor in determining the total error for the measurements made relates to landmark identification. This finding is consistent with published contemporary opinion.( Houston et al 1986)

The greatest method error values were recorded for angular variables involving the long axis of incisors, and indeed the greatest method error of all was $1.505^{o}$ for the interincisal angle ($IL_s$-$IL_i$), an angular measurement which utilises the long axis of both incisors. The greatest linear variable method error was recorded for the total anterior face height (n-gn) at 0.661mm.

The smallest method error value was observed for the measurement of the posterior face height (s-pm) at 0.236mm. The smallest angular method error value was $0.296^{o}$ for SNB. (s-n-sm)

Considering the results of the method error test as a whole the results allow comparison with two published studies which quantified the method error inherent in assessment of cephalometric variables using the technique described. Sandler (1988) used the parameter of standard deviation of the difference between two determinations of the same variable, and examined a broadly similar range of variables to those investigated in this study. Gravely and Benzies (1974) quoted two parameters, namely the method error statistic and also the 95% confidence limit for error. All three of these parameters were determined in this study and are quoted in Table 13.

The results of this test can be compared to the published work mentioned above in two ways. Firstly, the relative susceptibility of cephalometric variables to error in this study matches quite closely that observed by Sandler (1988), and Gravely and Benzies (1974). Most obvious in this respect is that measurements involving the long axis of an incisor tooth are susceptible to the greatest degree of error due to difficulty in identifying the position of incisor apices.

It is also possible to consider the magnitude of the error observed in this test with the published data. The results reported here are of the same order as those published by the authors mentioned above but do demonstrate a small trend towards being somewhat smaller.

Although no statistical comparisons have been made, the results of this test suggest that the method used to measure the cephalometric variables in this study was no more susceptible to error than other similar published reports. Such error as was present was due principally to difficulties of landmark identification.

C. Study Model Analysis.

As described in Chapter 5, at total of nine variables were determined from orthodontic study models for all 44 subjects in both the study and control groups. A single examiner technique was utilised to eliminate inter-examiner variation.

To assess intra-examiner variation in this part of the study a random sample of twenty sets of the study models were examined twice for the occlusal and dental variables using the conventions described in Chapter 5.

The repeat examinations of the study models were carried out with an interval of two weeks between the first and second assessments to reduce any memory bias. Both study group and control group study models were represented in the test ( 10 of each ) although apart from this factor the subjects were selected at random.

As each variable was determined for each case, the value was written down by a recorder. Neither the examiner nor the recorder was aware of the first reading when the second reading was being determined two weeks later, and only once all readings had been made was any evaluation of reproducibility made.

The nine variables can be grouped into three types according to the way they were determined. Maxillary Intermolar Width, Maxillary Intercanine Width, Mandibular Intermolar Width, and Mandibular Intercanine Width were

all quantitative variables measured to the nearest 0.1mm. Incisor Overjet and Palatal Vault Depth were quantitative variables measured to the nearest 0.5mm.
Incisor Overbite, Buccal Crossbites and Index of Orthodontic Treatment Need - Dental Health Component were all categorical variables. Different methods were used to examine repeatability of the quantitative data and the categorical data.

(i) Quantitative study model variables.
For each of the quantitative variables the difference between the first and second readings was calculated. The maximum, minimum and mean difference together with the standard deviation were calculated for each of the quantitative variables. The method error statistic was calculated using the following formula as described by Bland (1987) :-

$$\text{Method error (s)} = \sqrt{\frac{1}{2\,n}\sum(x_i - y_i)^2}$$

Where $x_i$ and $y_i$ are the pairs of repeat measurements for $i = 1$ to $n$.

In addition, the 95% confidence level for error was calculated using the following formula as recommended by the British standards Institution (1979)

$$95\% \text{ limit} = 1.96 \times \sqrt{2\,s^2}$$

Table 14 details the range of errors recorded, the mean difference and standard deviation, the method error value and the 95% confidence limit for error for each of the quantitative variables.

From Table 14 it can be seen that the errors encountered for the quantitative study model variables were relatively small, with maximum errors of 1.0mm seen in the cases of Overjet and Palatal Vault Depth. The very small mean error values for all the variables indicates that there was little tendency for either the first or second readings to be consistently larger. The largest method error (s) was recorded for Palatal Vault Depth, and even in this case, the 95% confidence limit for error was less than three-quarters of a millimetre.

Table 14.

Calculation of total method error for each of the quantitative variables measured from study models, as determined by duplicated assessment of twenty cases. "Error" quoted is defined as the difference between the first and second measured values for each variable. All dimensions are in millimetres.

| Variable | Error range | Mean Error | Error Standard Deviation | Method Error (s) | 95% Conf. Limit |
|---|---|---|---|---|---|
| Maxillary Intermolar Width. | +0.5 to -0.8 | **-0.05** | 0.302 | **0.210** | 0.58mm |
| Maxillary Intercanine Width. | +0.4 to -0.9 | **-0.05** | 0.347 | **0.240** | 0.67mm |
| Palatal Vault Depth. | +1.0 to -0.5 | **0.08** | 0.373 | **0.262** | 0.73mm |
| Mandibular Intermolar Width. | +0.4 to -0.2 | **0.08** | 0.185 | **0.140** | 0.39mm |
| Mandibular Intercanine Width. | +0.3 to -0.5 | **-0.02** | 0.223 | **0.154** | 0.43mm |
| Incisor Overjet. | +1.0 to -0.5 | **0.00** | 0.324 | **0.224** | 0.62mm |

(ii) Categorical study model variables.

Intra-examiner repeatability was assessed using two parameters, namely the percentage perfect agreement and the Kappa statistic (Landis and Koch, 1977). The Kappa statistic is used as a measure of agreement beyond that solely due to chance. Zero represents random or chance agreement, while 1.00 represents perfect agreement.

Previous studies of categorical data determined from orthodontic study models have utilised the Kappa Statistic to evaluate the degree of inter-examiner repeatability and also intra-examiner repeatability. (Brook and Shaw 1989, Holms 1992). As a "benchmark" for interpretation of the statistic, Landis and Koch (1977) published a table linking the Kappa Statistic to Strength of Agreement, and this table is reproduced as Table 15. A description of the method of calculating the Kappa Statistic is given in Appendix A.

Table 15.

Interpretation of Kappa Statistic values in the evaluation of repeatability of categorical variables.

Source: Landis and Koch (1977)

| Kappa Statistic | Strength of Agreement |
|---|---|
| < 0.00 | Poor |
| 0.00 - 0.20 | Slight |
| 0.21 - 0.40 | Fair |
| 0.41 - 0.60 | Moderate |
| 0.61 - 0.80 | Substantial |
| 0.81 - 1.00 | Almost Perfect |

(a) Incisor Overbite. Perfect agreement between the first and second readings of incisor overbite was recorded for 18 of the 20 cases, representing 90% perfect agreement. The remaining two cases had a difference of only one category; one case was scored grade 5 on the first reading and grade 4 on the second, and the other case was scored grade 4 on the first reading and grade 5 on the second. All 6 possible categories of overbite were represented in the 20 cases used for the repeatability test. The Kappa statistic for incisor overbite was 0.87, indicating almost perfect strength of agreement.

(b) Buccal Segment Crossbites. Perfect agreement between the first and second readings for buccal segment crossbite was observed in all 20 cases (100%). The Kappa statistic for this variable was 1.00 indicating perfect strength of agreement.

Although the repeatability of the crossbite assessment was in theory perfect, it is important to note that not all possible categories of crossbite were observed in the 20 cases tested. Only categories 1, 2 and 3 were encountered. No cases were found to have category 4 (Bilateral crossbite) or category 5 (lingual crossbite) amongst the 20 cases used for the repeatability test, and so repeatability of these categories was not fully tested.

(c) Index of Orthodontic Treatment Need - Dental Health Component. Perfect agreement between first and second readings for this variable was recorded for 18 of the 20 cases tested, representing 90% perfect agreement. The two cases which had different scores on each assessment were both scored Grade 5 on the first assessment and Grade 4 on the second assessment. No case differed by more than one category between the first and second assessment. All 5 possible categories of I.O.T.N. were represented in the 20 cases used for the repeatability test. The Kappa statistic for I.O.T.N. was 0.85, indicating almost perfect strength of agreement.

These values compare well with intra-examiner repeatability achieved in a study of a similar group of subjects reported by Holmes (1992). She reported 88% perfect agreement for I.O.T.N.- D.H.C., and a Kappa value of 0.84. Furthermore, in their initial paper describing the Index of Orthodontic Treatment Need, Brook and Shaw (1989) reported a Kappa Statistic of 0.84 for intra-examiner repeatability for assessment of a referred population.

From these calculations, it was concluded that the assessment of Incisor Overbite, Buccal Segment Crossbite and I.O.T.N. - D.H.C. according to the protocol described in Chapter 5 achieved an acceptable level of repeatability when compared to similar published studies.

# CHAPTER 7

# RESULTS

## A. Prevalence of digit sucking habits.

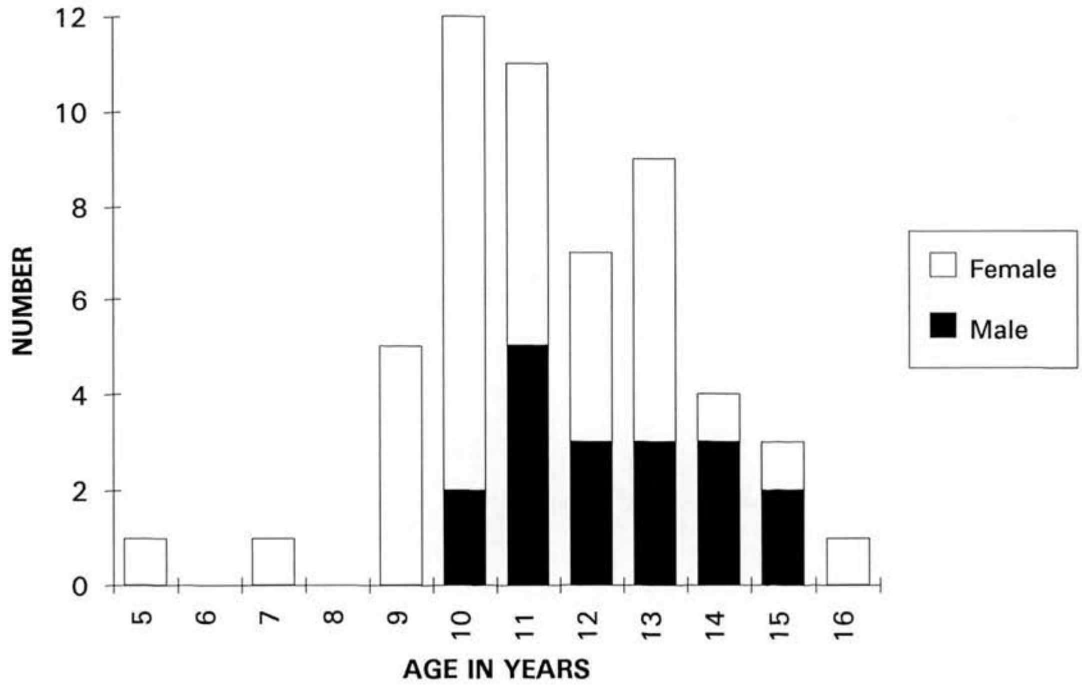
The prevalence of digit sucking amongst new patients has already been reported in Chapter 4, and the results are repeated here for clarity. During the period from 1-1-92 to 31-8-92 ( 8 months) a total of 885 new patient consultations were conducted in the Orthodontic Department, Victoria Hospital, Kirkcaldy. Of the 885 patients, 54 were found to have a continuing digit sucking habit as determined by enquiry by the examining Orthodontist. This represents 6.1% of all new patient consultations.

The age and sex distribution of the cases found to have a history of persisting digit sucking habit is illustrated in Figure 11. The mean age at the time of consultation was 11.4 years, with a range from 5 years to 16 years. 36 cases (66%) were female and 18 cases (33%) were male.

According to the criteria laid down in Chapter 4, a study group consisting of 44 of the persistant digit suckers was identified, and the remaining results in this chapter relate to these subjects.

Figure 11.

Age and sex distribution of the 54 patients found to have a persistant digit sucking habit at their initial consultation.



B. Historical features of the digit sucking habits.

(i) Which hand and digit was involved.

Table 16 presents the results of the enquiry into which hand and digit was reported to be sucked by the Study Group subjects.

Over half of the subjects reported that they sucked a right hand digit, while almost a third of subjects sucked a left hand digit. Notably, 18% of the subjects indicated that they did not have a particular hand which was favoured and sucked digits from either hand.

Almost 90% of the subjects identified the thumb as the digit which they routinely sucked. The remainder of the Study Group reported a number of more unique sucking patterns involving one or more fingers.

Table 16.

Cross tabulation of responses to enquiry into which digit was routinely sucked, and on which hand the sucked digit was, for the Study Group subjects.

| | | HAND | | | |
|---|---|---|---|---|---|
| | | RIGHT | LEFT | VARIABLE | Row Total |
| DIGIT | Thumb | 20 | 11 | 8 | 39 (88.6%) |
| | Index | 0 | 1 | 0 | 1 (2.3%) |
| | Middle | 0 | 0 | 0 | 0 |
| | Ring | 0 | 0 | 0 | 0 |
| | Little | 0 | 0 | 0 | 0 |
| | Multiple | 2 | 1 | 0 | 3 (6.8%) |
| | Single, Variable | 1 | 0 | 0 | 1 (2.3%) |
| Column Totals | | 23 (52.3%) | 13 (29.5%) | 8 (18.2%) | 44 (100%) |

(ii) Which surface of the digit lies uppermost.

When asked to demonstrate which surface of the sucked digit lies uppermost in the mouth while it was being sucked, 42 subjects (95.5%) identified the ventral (palmar) surface and 2 (4.5%) identified the dorsal (knuckle) surface.

When data for which digit was combined with data for which surface uppermost three different sucking patterns were noted.

Firstly, all 39 subjects (88.6%) who reported sucking their thumb demonstrated their sucking technique with the palmar surface of the thumb uppermost. Figure 12 illustrates a subject from the Study Group who demonstrated this pattern.

Secondly, of the 5 subjects with finger sucking habits, 3 subjects (6.8%) demonstrated sucking their finger(s) with the palmar surface uppermost. Figure 13 illustrates a subject from the Study Group with this sucking pattern.

Thirdly, the remaining 2 subjects (4.5%) with a finger sucking habit demonstrated sucking their fingers with the dorsal (knuckle) surface uppermost. Figure 14 illustrates a subject from the Study Group with this sucking pattern.

Figure 12.

Photograph of a subject from the Study Group who demonstrated a pattern of sucking their thumb with the palmar surface uppermost. 88.6% of the Study Group demonstrated a pattern of sucking similar to this.

Figure 13.

Photograph of a subject from the Study Group who demonstrated a pattern of sucking a finger with the palmar surface uppermost. 6.8% of the Study Group demonstrated a sucking pattern similar to this.

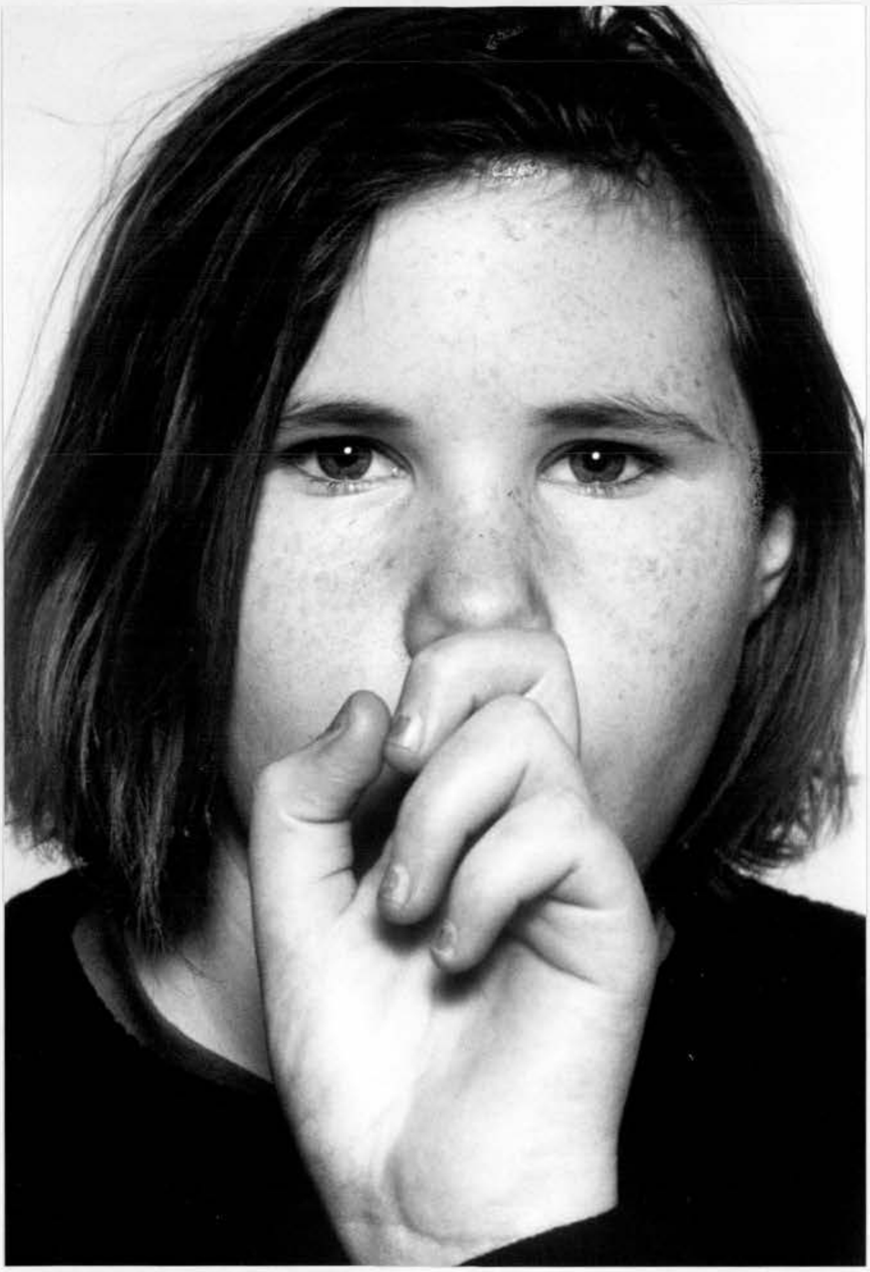
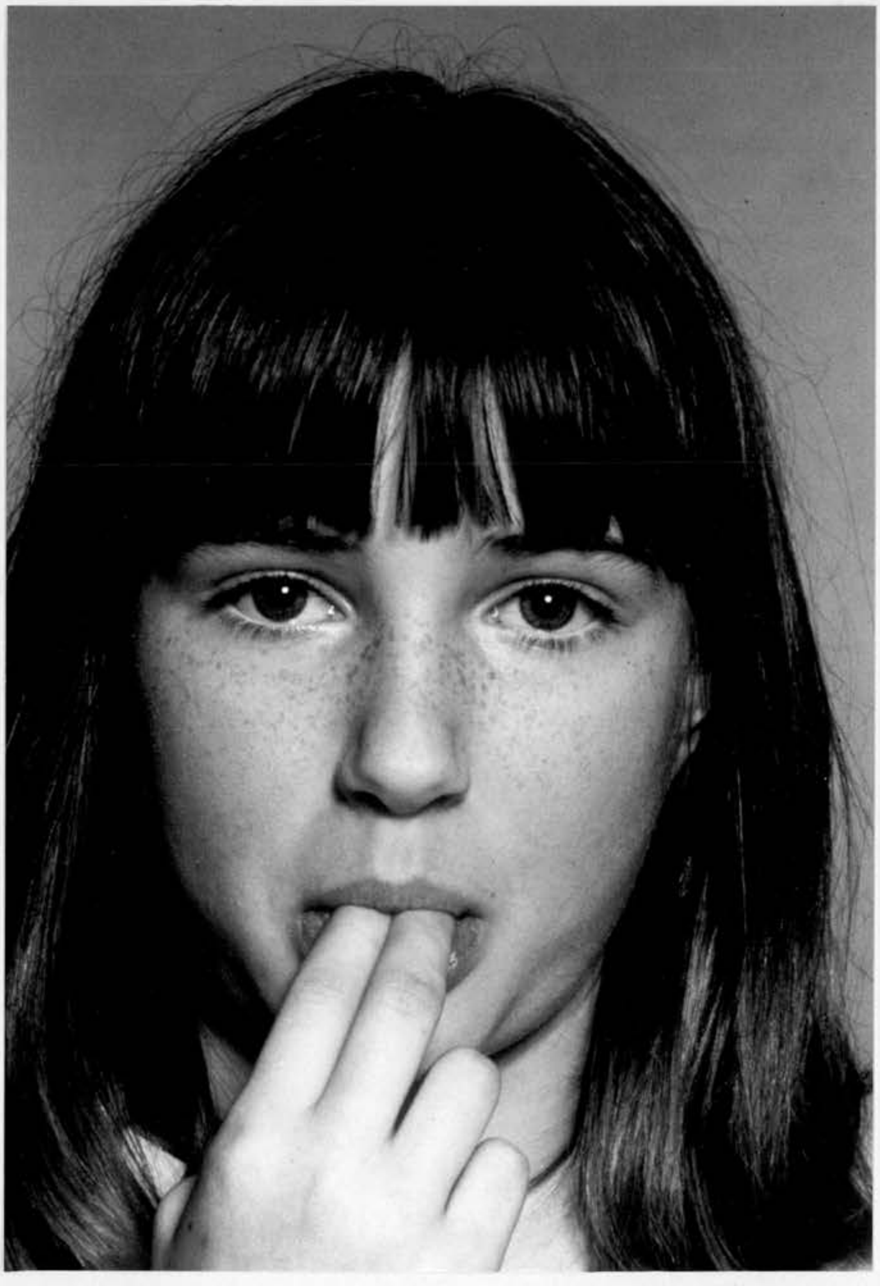


Figure 14.

Photograph of a subject from the Study Group who demonstrated a pattern of sucking a finger with the dorsal surface uppermost. 4.5% of the Study Group demonstrated a sucking pattern similar to this.



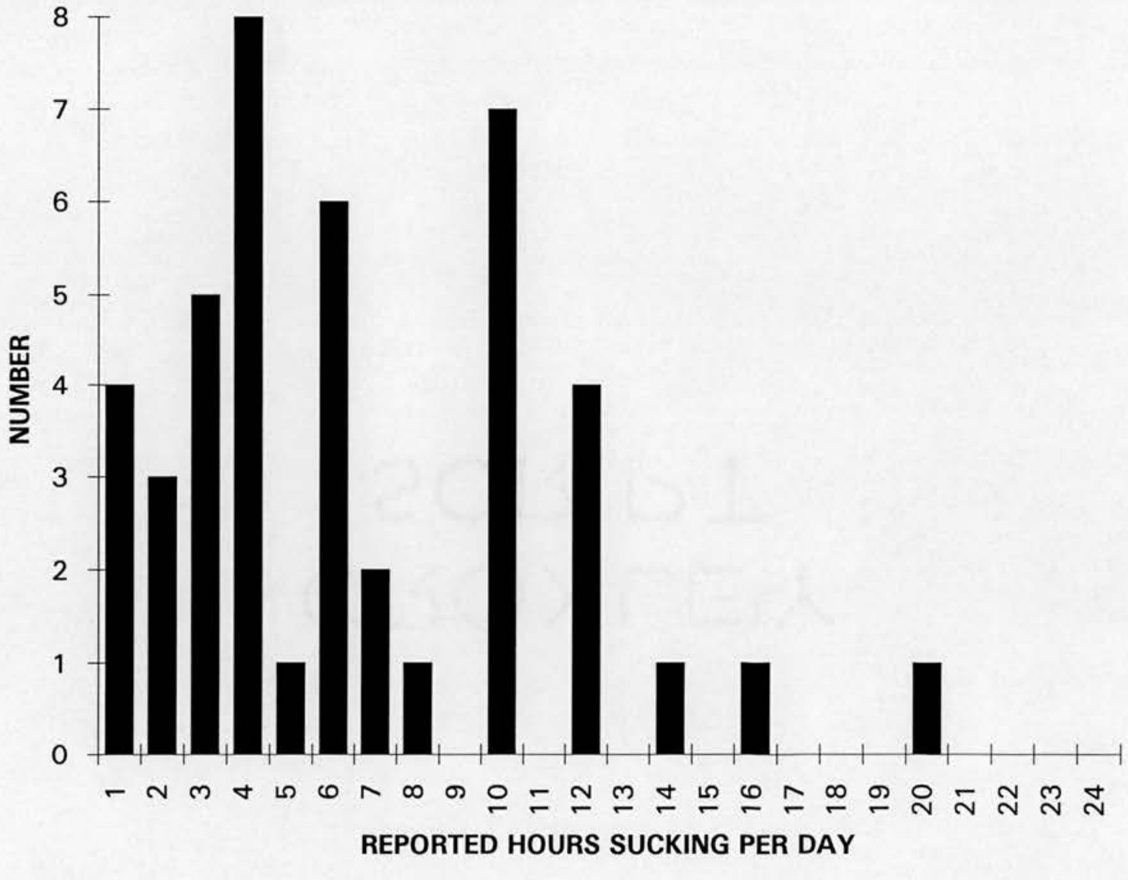
(iii) Reported daily duration of sucking.

When the subjects in the study group were asked to estimate how many hours per day (to the nearest hour) they actually sucked their digits the replies ranged from a minimum of 1 hour to a maximum of 20 hours per day. The mean value was 6.5 hours, standard deviation 4.41.

Figure 15 illustrates the frequency distribution for each possible response. The distribution was found to be non-parametric and positively skewed, and so the median value of 6 hours is probably the most appropriate measure of central tendency.

Figure 15.

Frequency distribution of the reported hour of digit sucking per day for the Study Group (N=44).



(iv) Associations / times of the day.

All subjects in the study group were asked if there were any special times of the day or activities which were associated with their digit sucking habit. Only 4 subjects (9.1%) reported that there were no special associations.

A majority of 37 subjects (84.1%) reported that their habit was mainly associated with either being tired or being in bed. Of the remaining three subjects, one reported that the habit could occur at "any time" and two said that their habits were virtually constant.

None of the study group reported any association of their habit with comforting blankets or the concurrent presence of other habits, such as hair pulling while they were actively digit sucking.

C. Cephalometric analysis of craniofacial morphology.

(i) Results for each group.

The results for the 19 cephalometric variables for the study group and control group are show in Table 17 and Table 18 respectively. Each table shows the range in terms of minimum and maximum values, the mean, the standard error of the mean and the standard deviation for each of the cephalometric variables.

(ii) Comparison of the study group with the control group.

Prior to statistical analysis, frequency distributions for each variable were examined. The frequency distributions demonstrated that all variables conformed well to a Normal distribution curve, with approximately 95% of observations being within +/- 2 standard deviations, approximately 68% of observations being within +/- 1 standard deviation of the mean and close agreement in the values for the mean and the median for each variable. Parametric statistical methods were therefore considered appropriate.

The results of the comparison between the study group and the control group are shown in Table 19. For each of the 19 cephalometric variables the following parameters are listed:- Study group mean value, control group mean value, difference between the means, value of "t" (student's t test) and value of P. Six variables were found to have differences which were significant at the 1% level ( $P < 0.01$ ) and another was found to have a difference which was significant at the 5% level ( $0.05 > P > 0.01$ ).

Table 17.

Results of the cephalometric analysis for the Study Group ( n=44 ). Angular variables are quoted in degrees, linear variables in millimeters.

| Variable | Min | Max | Mean | Standard Error of the Mean | Standard Deviation |
|---|---|---|---|---|---|
| 1. s-n-ss | 76.8 | 92.8 | 83.668 | 0.560 | 3.714 |
| 2. s-n-sm | 70.1 | 87.5 | 78.320 | 0.548 | 3.635 |
| 3. ss-n-sm | 0.8 | 9.5 | 5.350 | 0.323 | 2.141 |
| 4. ba-s-n | 118.9 | 138.9 | 129.627 | 0.667 | 4.427 |
| 5. MXP-MNP | 16.1 | 40.2 | 28.068 | 0.729 | 4.833 |
| 6. $IL_s$-MXP | 100.4 | 126.3 | 113.909 | 0.882 | 5.848 |
| 7. $IL_i$-MNP | 69.5 | 107.0 | 94.132 | 1.179 | 7.819 |
| 8. $IL_i$-$IL_s$ | 104.2 | 150.0 | 123.893 | 1.494 | 9.909 |
| 9. $IL_s$-SNL | 94.0 | 127.8 | 108.183 | 1.034 | 6.858 |
| 10. MXP-SNL | -1.8 | 11.4 | 5.723 | 0.402 | 2.664 |
| 11. MNP-SNL | 22.9 | 43.5 | 33.789 | 0.767 | 5.088 |
| 12. pm-sp | 46.7 | 63.1 | 55.007 | 0.556 | 3.686 |
| 13. cd-gn | 99.3 | 134.8 | 115.125 | 1.016 | 6.737 |
| 14. n-sp | 40.4 | 56.8 | 49.670 | 0.507 | 3.364 |
| 15. sp-gn | 47.5 | 74.6 | 61.782 | 0.820 | 5.438 |
| 16. n-gn | 92.7 | 127.9 | 111.452 | 1.117 | 7.407 |
| 17. s-pm | 42.9 | 55.3 | 47.589 | 0.464 | 3.078 |
| 18. s-n | 65.3 | 82.0 | 72.518 | 0.547 | 3.630 |
| 19. s-ba | 36.6 | 54.9 | 47.327 | 0.607 | 4.029 |

Table 18.

Results of the cephalometric analysis for the Control Group ( n=44 ). Angular variables are quoted in degrees, linear variables in millimeters.

| Variable | Min | Max | Mean | Standard Error of the Mean | Standard Deviation |
|---|---|---|---|---|---|
| 1. s-n-ss | 73.1 | 88.3 | 80.925 | 0.591 | 3.922 |
| 2. s-n-sm | 69.5 | 86.8 | 77.316 | 0.618 | 4.098 |
| 3. ss-n-sm | -3.7 | 10.0 | 3.611 | 0.381 | 2.527 |
| 4. ba-s-n | 117.1 | 140.8 | 129.700 | 0.670 | 4.641 |
| 5. MXP-MNP | 14.7 | 51.6 | 27.568 | 0.917 | 6.081 |
| 6. $IL_s$-MXP | 77.2 | 122.5 | 106.173 | 1.379 | 9.144 |
| 7. $IL_i$-MNP | 78.4 | 110.5 | 93.757 | 1.047 | 6.946 |
| 8. $IL_i$-$IL_s$ | 103.8 | 171.1 | 133.191 | 2.262 | 15.002 |
| 9. $IL_s$-SNL | 71.8 | 114.9 | 98.791 | 1.394 | 9.245 |
| 10. MXP-SNL | 0.1 | 15.5 | 7.382 | 0.522 | 3.464 |
| 11. MNP-SNL | 23.5 | 50.3 | 34.268 | 0.751 | 4.981 |
| 12. pm-sp | 44.8 | 58.4 | 52.382 | 0.477 | 3.161 |
| 13. cd-gn | 97.4 | 124.2 | 113.884 | 0.993 | 6.594 |
| 14. n-sp | 43.6 | 59.3 | 50.141 | 0.494 | 3.276 |
| 15. sp-gn | 52.8 | 76.4 | 61.905 | 0.902 | 5.986 |
| 16. n-gn | 99.5 | 135.7 | 112.048 | 1.133 | 7.513 |
| 17. s-pm | 41.7 | 52.9 | 46.499 | 0.445 | 2.953 |
| 18. s-n | 65.9 | 81.1 | 71.520 | 0.573 | 3.801 |
| 19. s-ba | 38.2 | 53.3 | 47.334 | 0.470 | 3.116 |

Table 19.

Comparison of the mean values for each of the 19 cephalometric variables. Angular variables are quoted in degrees, linear variables in millimeters. For each group, n=44. Degrees of freedom for determination of P = 86.

| Variable | Study Group Mean | Control Group Mean | Difference Between Means | "t" Value | P Value |
|---|---|---|---|---|---|
| 1. s-n-ss | 83.668 | 80.925 | 2.743 | 3.368 | 0.0015 |
| 2. s-n-sm | 78.320 | 77.316 | 1.004 | 1.215 | 0.2249 |
| 3. ss-n-sm | 5.350 | 3.611 | 1.739 | 3.483 | 0.0011 |
| 4. ba-s-n | 129.627 | 129.700 | -0.073 | 0.075 | 0.9382 |
| 5. MXP-MNP | 28.068 | 27.568 | 0.500 | 0.427 | 0.6742 |
| 6. $IL_s$-MXP | 113.909 | 106.173 | 7.736 | 4.728 | <0.0001 |
| 7. $IL_i$-MNP | 94.132 | 93.757 | 0.375 | 0.238 | 0.8077 |
| 8. $IL_i$-$IL_s$ | 123.893 | 133.191 | 9.298 | 3.430 | 0.0013 |
| 9. $IL_s$-SNL | 108.182 | 98.791 | 9.391 | 5.412 | <0.0001 |
| 10. MXP-SNL | 5.723 | 7.382 | -1.659 | 2.518 | 0.0131 |
| 11. MNP-SNL | 33.789 | 34.268 | -0.479 | 0.446 | 0.6606 |
| 12. pm-sp | 55.007 | 52.382 | 2.625 | 3.586 | 0.0009 |
| 13. cd-gn | 115.125 | 113.884 | 1.241 | 0.873 | 0.6110 |
| 14. n-sp | 49.670 | 50.141 | -0.470 | 0.665 | 0.5151 |
| 15. sp-gn | 61.782 | 61.905 | -0.123 | 0.101 | 0.9168 |
| 16. n-gn | 111.452 | 112.048 | -0.596 | 0.375 | 0.7104 |
| 17. s-pm | 47.589 | 46.489 | 1.100 | 1.711 | 0.0869 |
| 18. s-n | 72.518 | 71.520 | 0.998 | 1.259 | 0.2088 |
| 19. s-ba | 47.327 | 47.334 | 0.007 | 0.009 | 0.9892 |

(iii) Comparison of individual cephalometric variables.

For convenience, the cephalometric variables are considered in logical functional groups.

(a) Measurements of prognathism.

A highly significant difference was observed between the two groups in the mean value of s-n-ss (SNA), which is a measure of maxillary prognathism. The value was found to be $2.74^{\circ}$ higher in the study group at $83.668^{\circ}$. The difference in the measure of mandibular prognathism, s-n-sm (SNB) was not found to be statistically significant, with the study group having a mean value just $1.00^{\circ}$ greater than the control group. Relative prognathism, as measured by the variable ss-n-sm (ANB), showed a highly significant difference between the groups, with the study group having a mean value of $5.35^{\circ}$, $1.74^{\circ}$ higher than the control group.

(b) Incisor angulation measurements.

Four variables measured antero-posterior incisor angulation relative to other structures. Two of these, $IL_s$-MXP and $IL_s$-SNL, measured maxillary incisor proclination relative to the maxillary plane and the anterior cranial base respectively. Both variables demonstrated that the maxillary incisors were more proclined in the study group compared to the control group. The difference between the means was $7.74^{\circ}$ for $IL_s$-MXP and $9.39^{\circ}$ for $IL_s$-SNL, both values showing an extremely high level of statistical significance.

No significant difference was observed in the proclination of the mandibular incisors relative to the mandibular plane as measured by the variable $IL_i$-MNP. The interincisal angle ($IL_s$-$IL_i$) was found to be significantly reduced in the study group, the value of $123.89^o$ being $9.30^o$ smaller than the corresponding value for the control group.

(c) Maxillary and mandibular relationships.

No significant difference was observed between the groups for either the angle between the maxillary and mandibular planes (MXP-MNP), nor the angle between the mandibular plane and the cranial base (MNP-SNL). However, a difference between the groups of $1.66^o$ was observed in the angulation of the maxillary plane relative to the cranial base (MXP-SNL) and this was found to be significant at the 5% level (P=0.013).

(d) Maxillary and mandibular lengths.

The mean maxillary length measured from the anterior nasal spine to the posterior nasal spine (pm-sp) was found to be 2.62mm greater in the study group when compared to the control group. This observation was found to be highly statistically significant, with a P value of 0.0009. However, the difference in mean mandibular length (cd-gn) for the two groups was smaller at 1.24mm, and was not found to be significant.

(e) Cranial base measurements.

Two linear and one angular cranial base measurements were compared between the study group and the control group. The length of the posterior cranial base (s-ba) and the angle of flexion of the cranial base were both found to differ to an extremely small degree between the study group and the control group. The largest difference between the two groups in relation to the cranial base measurements was for the length of the anterior cranial base (s-n) where the difference between the means was 0.998mm. For none of the cranial base measurements was the difference between the means for the two groups found to be statistically significant.

(f) Vertical height measurements.

Four measurements of facial height characteristics were determined directly from the cephalometric analysis.

Upper posterior face height was measured as the true distance between sella and the posterior nasal spine. The study group mean value was 47.589mm, and this was 1.100mm greater than the corresponding value for the control group. Although this difference did not achieve significance at the conventional levels of 5% or 1%, the P value of 0.0869 does suggest a possible trend towards statistical significance for this measurement.

Measurement of anterior face height was conducted by determination of three measurements which were all made as vertical distances, rather than true distances. The Dentofacial Planner was programmed to use the Frankfort Horizontal Plane, passing through the digitised points porion and orbitale, as the reference line for the orientation of the cephalometric features when making these vertical measurements. Mean values for upper anterior face height (n-sp), lower anterior face height (sp-gn) and total anterior face height (n-gn) were all found to have small differences between the study group and the control group. None of the differences for the anterior face height measurements achieved statistical significance.

In addition to the face height variables already mentioned, which were determined directly from the Dentofacial Planner measurements, a further variable was indirectly determined at the analysis stage and the mean value compared for the two groups. "Face height ratio" was calculated for each case by expressing the upper anterior face height as a percentage of the total anterior face height. The mean face height ratio for the study group was 44.566%, standard deviation 2.197. The mean face height ratio for the control group was 44.775%, standard deviation 2.523. The difference in mean face height ratio was 0.209%, and this was found to be not significant, with a P value of 0.683.

(iv) Summary of results - Cephalometric variables.

In summary, six of the cephalometric variables determined were found to have differences between the mean values for the two groups which were statistically significant at the 1% level. These variables were:-

s-n-ss (maxillary prognathism, SNA )

ss-n-sm (relative prognathism ANB)

$IL_s$-MXP (maxillary incisor angulation to maxillary plane)

$IL_i$-$IL_s$ (interincisal angle)

$IL_s$-SNL (maxillary incisor angulation to cranial base)

pm-sp (maxillary antero-posterior length)

One variable was found to have a difference between the mean values of the two groups which was significant at the 5% level:-

MXP-SNL (angulation of the maxillary plane relative to the cranial base)

The remaining cephalometric variables were not found to have significant differences between the two groups.

D. Dental and occlusal analysis of study models.

(i) Initial considerations.

A total of 9 variables were determined from study models of the study group and the control group. 6 variables were quantitative and 3 were categorical.

As a preliminary stage to the statistical analysis of the results for the quantitative variables, the results for all 88 subjects were examined together to assess their conformity to the natural distribution. Maxillary Intermolar Width, Maxillary Intercanine Width, Palatal Vault Depth, Mandibular Intermolar Width, Mandibular Intercanine Width and Incisor Overjet were all found to approximate to the normal distribution. This was assessed by examination of the frequency distribution for each variable, by checking that approximately 68% of cases were within +/- 1 standard deviation of the mean and approximately 95% of cases were within +/- 2 standard deviations of the mean, and by checking for close agreement between the parameters of mean and median. Parametric statistical techniques were therefore considered appropriate for the quantitative variables.

(ii) Results for each group- quantitative variables.

The results for the quantitative variables which were determined from the study models are given in Table 20 for the study group and Table 21 for the control group. For each variable, the statistical parameters of minimum and maximum (range), mean, standard error of the mean and standard deviation are given. It will be seen from the values of "n" from Tables 20 and 21 that a number of missing values exist for some of the variables. The missing values were encountered in subjects where teeth required to determine the variable were missing, due to extraction or the tooth being unerupted.

(iii) Comparison of results between the groups- quantitative variables.

Table 22 details the comparison of the quantitative variables between the two groups. For each variable, the statistical parameters of study group mean, control group mean, difference between the means (study group value - control group value), value of "t" (Student's t test) and corresponding value of P are given.

Table 20.

Results of the study model analysis of quantitative variables for the Study Group. All measurements are quoted in millimeters.

| Variable | Min | Max | Mean | Standard Error of the Mean | Standard Deviation |
|---|---|---|---|---|---|
| Maxillary Intermolar Width (n=44) | 31.0 | 43.2 | 36.97 | 0.426 | 2.828 |
| Maxillary Intercanine Width (n=29) | 26.6 | 37.1 | 31.70 | 0.552 | 2.974 |
| Palatal Vault Depth (n=44) | 11.5 | 21.0 | 17.64 | 0.335 | 2.219 |
| Mandibular Intermolar Width (n=43) | 26.5 | 40.4 | 33.60 | 0.481 | 3.153 |
| Mandibular Intercanine Width (n=35) | 21.7 | 30.4 | 26.58 | 0.334 | 1.978 |
| Incisor Overjet (n=44) | 0.0 | 12.0 | 6.70 | 0.421 | 2.790 |

Table 21.

Results of the study model analysis of quantitative variables for the Control Group. All measurements are quoted in millimeters.

| Variable | Min | Max | Mean | Standard Error of the Mean | Standard Deviation |
|---|---|---|---|---|---|
| Maxillary Intermolar Width (n=43) | 31.9 | 43.9 | 37.64 | 0.430 | 2.952 |
| Maxillary Intercanine Width (n=31) | 27.2 | 39.4 | 33.44 | 0.460 | 2.561 |
| Palatal Vault Depth (n=44) | 15.0 | 22.5 | 17.76 | 0.271 | 1.800 |
| Mandibular Intermolar Width (n=40) | 26.9 | 41.0 | 32.91 | 0.495 | 3.131 |
| Mandibular Intercanine Width (n=42) | 21.0 | 32.3 | 25.70 | 0.362 | 2.348 |
| Incisor Overjet (n=44) | 0.0 | 9.5 | 3.61 | 0.371 | 2.461 |

Table 22.

Comparison of the mean values for each of the quantitative study model variables using the Student's t test. All measurements are quoted in millimeters. Degrees of freedom for determination of P value = $(n_1-1)+(n_2-1)$.

| Variable | Study Group Mean | Control Group Mean | Difference Between Means | "t" Value | P Value |
|---|---|---|---|---|---|
| Maxillary Intermolar Width | 36.97 (n=44) | 37.64 (n=43) | -0.67 | 1.082 | 0.281 (df=85) |
| Maxillary Intercanine Width | 31.70 (n=29) | 33.44 (n=31) | -1.74 | 2.421 | 0.018 (df=58) |
| Palatal Vault Depth | 17.64 (n=44) | 17.76 (n=44) | -0.12 | 0.290 | 0.770 (df=86) |
| Mandibular Intermolar Width | 33.60 (n=43) | 32.92 (n=40) | 0.68 | 0.985 | 0.675 (df=81) |
| Mandibular Intercanine Width | 26.58 (n=35) | 25.70 (n=42) | 0.88 | 1.791 | 0.078 (df=75) |
| Incisor Overjet | 6.70 (n=44) | 3.61 (n=44) | 3.09 | 5.509 | <0.001 (df=86) |

From Table 22 it can be seen that Maxillary Intercanine Width was found to be 1.74mm smaller in the study group, compared to the control group, and this difference was statistically significant at the 5% level. Maxillary Intermolar Width was also found to be smaller in the study group than in the control group, although in this case the difference of 0.67mm failed to reach statistical significance.

Both Mandibular Intercanine and Intermolar widths were found to be greater in the study group, but again these differences were not statistically significant. However the difference of 0.88mm in the Mandibular Intercanine Width did show a trend towards significance with a P value of 0.078.

Very little difference was observed between the two groups for the variable Palatal Vault Depth, and the difference failed to reach any level of significance.

Incisor Overjet was found to differ to a substantial amount between the two groups. The mean overjet of 6.70mm for the study group was almost twice the corresponding value of 3.61mm for the control group. The difference between the means of 3.09mm was found to be highly statistically significant.

(iv) Results for categorical variables.

"Incisor Overbite", "Buccal Crossbite", and "Index of Orthodontic Treatment Need" were all categorical variables and were analysed using the Chi square test as detailed below.

(v) Results for Incisor Overbite.

Table 23 presents a cross tabulation of "Incisor Overbite" with "Group". Calculation of the "expected" value for each cell for the determination of the Chi square parameter revealed that 6 of the cells had an expected value less than 5. Cochran (1954) states that the Chi square test is inappropriate for contingency tables with more than one degree of freedom if more than one fifth of the cells have an expected value less than 5.

In order to conduct a Chi square test, the data were therefore recoded into three categories of overbite. Overbite categories 1, 2, and 3 (as described in Chapter 5) were recoded as "Open". Category 4 was recoded as "Normal" and categories 5 and 6 were recoded as "Deep". Table 24 presents a cross tabulation of the revised overbite categories for each of the two groups.

Table 23.

Cross tabulation of "Incisor Overbite Category" with "Group". Actual numbers are quoted.

| | | GROUP | | |
|---|---|---|---|---|
| | | 1 (study) | 2 (control) | Row Total |
| Overbite Category | 1 | 4 | 0 | 4 |
| | 2 | 7 | 1 | 8 |
| | 3 | 20 | 4 | 24 |
| | 4 | 9 | 20 | 29 |
| | 5 | 4 | 12 | 16 |
| | 6 | 0 | 7 | 7 |
| Column Totals | | 44 | 44 | 88 |

Table 24.

Cross tabulation of "Recoded Overbite Category" with "Group". Actual numbers are quoted.

| | | GROUP | | |
|---|---|---|---|---|
| | | 1 (study) | 2 (control) | Row Total |
| Recoded Overbite Category | Open | 31 | 5 | 36 |
| | Normal | 9 | 20 | 29 |
| | Deep | 4 | 19 | 23 |
| Column Totals | | 44 | 44 | 88 |

Chi Square = 32.73

Degrees of freedom = 2

P value = <0.0001

Following the recoding of overbite categories, the criteria described by Cochran (1954) for using the Chi square test were fulfilled. The Chi square value was 32.73, (degrees of freedom = 2) representing a P value less than 0.0001.

The difference in distribution of the revised overbite categories between the study group and the control group was concluded to be statistically significant.

(vi) Results for Buccal Crossbite.

Table 25 presents a cross tabulation of "Buccal Crossbite" with "Group". It was found that more than one fifth of the cells had an "expected" value less than 5 indicating that the Chi Square test was not appropriate for the data in this form. Furthermore, even elimination of the line corresponding to Crossbite code 5 which contained no observed cases did not fulfill the criteria for the validity of the Chi square test.

In a similar manner to the analysis of overbite, the buccal crossbite categories were therefore recoded. Two new codes were formulated. Code 1 as described in Chapter 5 was recoded as "No Crossbite Present" and codes 2,3,4 and 5 were recoded as "Crossbite Present". Table 26 presents the cross tabulation of "Recoded Buccal Crossbite Category" with "Group". This cross tabulation was found to fulfill the requirements for the Chi Square test.

Table 25.

Cross tabulation of "Buccal Crossbite Category" with "Group". Actual numbers are quoted.

| | | GROUP | | |
|---|---|---|---|---|
| | | 1 (study) | 2 (control) | Row Total |
| Buccal Crossbite Category | 1 | 30 | 38 | 68 |
| | 2 | 9 | 6 | 15 |
| | 3 | 4 | 0 | 4 |
| | 4 | 1 | 0 | 1 |
| | 5 | 0 | 0 | 0 |
| Column Totals | | 44 | 44 | 88 |

Table 26.

Cross tabulation of "Recoded Buccal Crossbite Category" with "Group". Actual numbers are quoted.

| | | GROUP 1 (study) | GROUP 2 (control) | Row Total |
|---|---|---|---|---|
| Recoded Buccal Crossbite Category | Crossbite Absent | **30** | **38** | 68 |
| | Crossbite Present | **14** | **6** | 20 |
| Column Totals | | 44 | 44 | 88 |

Uncorrected Chi Square = 4.14

Degrees of freedom = 1

P value = 0.042

Yates Corrected Chi Square = 3.17

P value = 0.075

Following the recoding of the Buccal Crossbite data, the Chi square value was calculated as 4.14, P = 0.042, which would suggest that the difference in distribution of the Recoded Buccal Crossbite Categories between the two groups was statistically significant. However, with 2x2 contingency tables the Yates Correction (Yates 1934) is indicated if the total number is less than 100. (Swinscow 1981). The Yates corrected Chi square value for Recoded Buccal Crossbite Category was 3.17, with a P value of 0.075. It was concluded that the difference in distribution of presence or absence of buccal crossbite between the two groups did not reach the 5% level of statistical significance.

(vii)Results for Index of Orthodontic Treatment Need - Dental Health Component.

Table 27 presents a cross tabulation of the results for "I.O.T.N." with "Group". The contingency table was found to contain more than one fifth of cells with "expected" values of less than 5 and recoding was necessary for the Chi square analysis. The I.O.T.N. has been validated by the opinion of 74 dentists ( Richmond 1990) and the Grades can be interpreted in three groups:- Grade 1 and 2 - No need for treatment, Grade 3 - Moderate / Borderline need for treatment. Grade 4 and 5 - Definite need for treatment. The data for I.O.T.N. were recoded into three categories accordingly, and the cross tabulation of these categories with "Group" is presented in Table 28.

Table 27.

Cross tabulation of "Index of Orthodontic Treatment Need - Dental Health Component " with "Group". Actual numbers are quoted.

| | | GROUP | | |
|---|---|---|---|---|
| | | 1 (study) | 2 (control) | Row Total |
| Index of Orthodontic Treatment Need | 1 | **0** | **3** | 3 |
| | 2 | **1** | **1** | 2 |
| | 3 | **9** | **9** | 18 |
| | 4 | **17** | **13** | 30 |
| | 5 | **17** | **18** | 35 |
| Column Totals | | 44 | 44 | 88 |

Table 28.

Cross tabulation of "Recoded Index of Orthodontic Treatment Need" with "Group". Actual numbers are quoted.

| Recoded Index Of Orthodontic Treatment Need | | GROUP 1 (study) | 2 (control) | Row Total |
|---|---|---|---|---|
| | No Need | **1** | **4** | 5 |
| | Moderate Need | **9** | **9** | 18 |
| | Definite Need | **34** | **31** | 65 |
| Column Totals | | 44 | 44 | 88 |

Chi square = 1.94

Degrees of freedom = 2

P value = 0.3794

Following the recoding of the I.O.T.N. data, the Chi Square value was calculated as 1.94, with a P value of 0.379. It was concluded that there was no significant difference in the distribution of Index of Orthodontic Treatment Need - Dental Health Component between the two groups under investigation.

E. Intra-group statistical comparison for the Study Group.

(i) Introduction.

The data collected relating to the history of the digit sucking habits facilitated subdivision of the Study Group for further comparison, and also allowed for investigation of possible "dose related" effects of digit sucking on the cephalometric and study model variables.

It had been hoped that collection of data on the type of digit sucking pattern would facilitate sub-division of the Study Group. However, although three modes of sucking were identified, it was found that 39 subjects sucked their thumbs, palmar surface uppermost. Only 3 subjects sucked fingers, palmar surface uppermost and only 2 subjects sucked fingers with the knuckle uppermost. As a result of the very small number of subjects in the latter two groups, meaningful comparison of the different modes of sucking and their influence on the cephalometric and study model variables was not possible.

Subdivision of the study group was carried out with respect to the age, sex and reported hours of digit sucking per day.

(ii) Historical Characteristics.

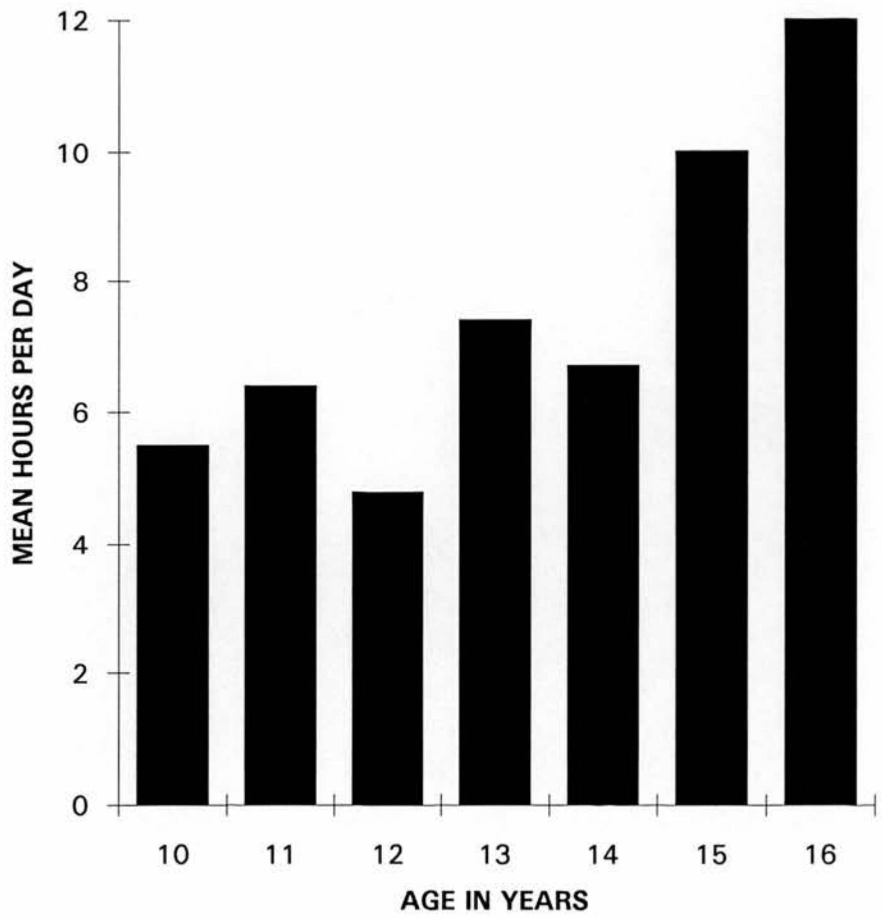
(a) Reported hours of digit sucking and subject's age.

The reported daily hours of sucking was broken down to examine the relationship between age and reported daily hours of digit sucking. The Study Group was subdivided into 7 sub-groups, according to age in years. The mean reported hours of digit sucking per day was calculated for each age group.

Figure 16 shows a bar chart of mean hour of sucking per day for each age in years. The bar chart suggests a trend towards greater duration of sucking in the older subjects. The relationship between age and reported daily duration of sucking was further investigated as detailed below.

Figure 16.

Bar chart showing the mean reported hours of digit sucking per day for each age (in years) of the study group.



The non-parametric nature of the data on hours of digit sucking has already been demonstrated in Figure 15 (page 156). In view of this, Kendall's Rank Correlation Test (Kendall 1970) was used to statistically examine the relationship between age and hours of digit sucking. The test was conducted as described by Swinscow (1981) using the modification of the test for tied values. The Kendall Rank Correlation Coefficient was calculated as 0.260 .

The value of P-Q, calculated as described by Kendall (1970) was 212, with a standard error of 98.87 "P-Q" therefore represented 2.144 times it's standard error. The correlation coefficient was therefore statistically significant at the 5% level.

(b) Reported hours of digit sucking and subject's sex.

The Female:Male ratio in the study group was 29:15. Table 29 presents the results of analysis of reported hours digit sucking per day for each sex.

In view of the non-parametric nature of the data on hours of digit sucking, the Mann-Whitney Rank Sum Test for unmatched samples was used to test the significance of the observed difference between the reported hours digit sucking for males and females. The P value for this test was 0.063, d.f.=1, and so the null hypothesis that there was no difference in the reported hours of digit sucking between the sexes could not be rejected.

Table 29.

Results of the analysis of "Reported hours digit sucking per day" for the Study Group, subdivided by sex. Values are quoted in hours

| Sex | Min | Max | Mean | Median | Standard Deviation | Standard Error of the Mean |
|---|---|---|---|---|---|---|
| Male (n=15) | 3 | 14 | 7.8 | 6.0 | 3.745 | 0.967 |
| Female (n=29) | 1 | 20 | 5.9 | 4.0 | 4.639 | 0.861 |

Difference = 1.9 hours.

Mann-Whitney Two Sample Test

Degrees of freedom = 1

P value = 0.063

(iii) Cephalometric Variables.

Intra-group analysis of the Study Group results for cephalometric variables was carried out with respect to the historical variable of reported hours digit sucking per day. Only the seven cephalometric variables which had previously been shown to be significantly different between the Study Group and the Control Group were analysed in this stage. The variables analysed were therefore as follows :-

s-n-ss (maxillary prognathism, SNA)

ss-n-sm (relative prognathism, ANB)

$IL_s$-MXP (maxillary incisor angulation to maxillary plane)

$IL_i$-$IL_s$ (interincisal angle)

$IL_s$-SNL (maxillary incisor angulation to cranial base)

pm-sp (maxillary antero-posterior length)

MXP-SNL (angulation of maxillary plane relative to the anterior cranial base)

The first test of "dose related " effects of digit sucking on the variables was to investigate the correlation between Reported Hours Digit Sucking per Day and each variable. Table 30 presents the results of the correlation analysis, and for each variable the statistical parameters of the Pearson Correlation Coefficient (r) together with the corresponding values of "t" and "P" is quoted. The value "P" is an indication of the statistical significance of the deviation of "r" away from zero, or no correlation.

Table 30.

Results of the correlation analysis for each of seven cephalometric variables correlated to the historical variable "Reported Hours Digit Sucking per Day".

| Variable | Pearson Correlation Coefficient (r) | t value | P value |
|---|---|---|---|
| s-n-ss | -0.08 | 0.520 | >0.5 |
| ss-n-sm | 0.04 | 0.259 | >0.5 |
| $IL_s$-MXP | 0.01 | 0.065 | >0.5 |
| $IL_i$-$IL_s$ | 0.11 | 0.717 | <0.5, >0.1 |
| $IL_s$-SNL | 0.04 | 0.259 | >0.5 |
| pm-sp | 0.09 | 0.586 | >0.5 |
| MXP-SNL | -0.09 | 0.586 | >0.5 |

From Table 30 it can be seen that correlation between the cephalometric variables and Reported Hours of Digit Sucking was extremely weak, and that for no variable tested did the correlation differ significantly from zero.

As a further test of possible dose related effects of digit sucking on the cephalometric variables the Study Group was sub-divided into two groups of similar size according to their reported hours of sucking. Those who reported sucking 5 hours or less per day were grouped as "Low Duration" (n=21) while those who reported sucking 6 hours or more per day were sub-grouped as "High Duration" (n=23).

For each of the 7 cephalometric variables being tested the mean value for the Low Duration and High Duration sub-groups was determined. The differences between the means were calculated, together with the values for "t"(Student's t test) and "P".

Table 31 presents the results of the comparison between the two sub-groups for the 7 cephalometric variables.

Table 31.

Comparison of the mean value of 7 cephalometric variables between the Low Duration and High Duration sub-groups of the total Study Group. Angular variables are quoted in degrees, linear variables are quoted in millimetres.

| Variable | "Low" Sub-group Mean | "High" Sub-group Mean | Difference Between Means | "t" Value | P Value |
|---|---|---|---|---|---|
| s-n-ss | 83.686 | 83.652 | 0.034 | 0.030 | 0.975 |
| ss-n-sm | 5.124 | 5.557 | -0.433 | 0.660 | 0.516 |
| $IL_s$-MXP | 112.324 | 115.357 | -3.033 | 1.803 | 0.082 |
| $IL_i$-$IL_s$ | 124.819 | 123.048 | 1.771 | 0.596 | 0.567 |
| $IL_s$-SNL | 106.429 | 109.783 | -3.354 | 1.693 | 0.102 |
| pm-sp | 54.310 | 55.643 | -1.334 | 1.224 | 0.233 |
| MXP-SNL | 5.886 | 5.574 | 0.312 | 0.389 | 0.705 |

Using the Student's t test, no significant differences for the cephalometric variables tested were noted between the "Low" and "High" Sub-groups of the Study group. It was noted, however, that for all but one of the 7 variables tested in this way trends were in the same direction as those observed when the Study Group was compared with the Control Group of non-digit suckers.

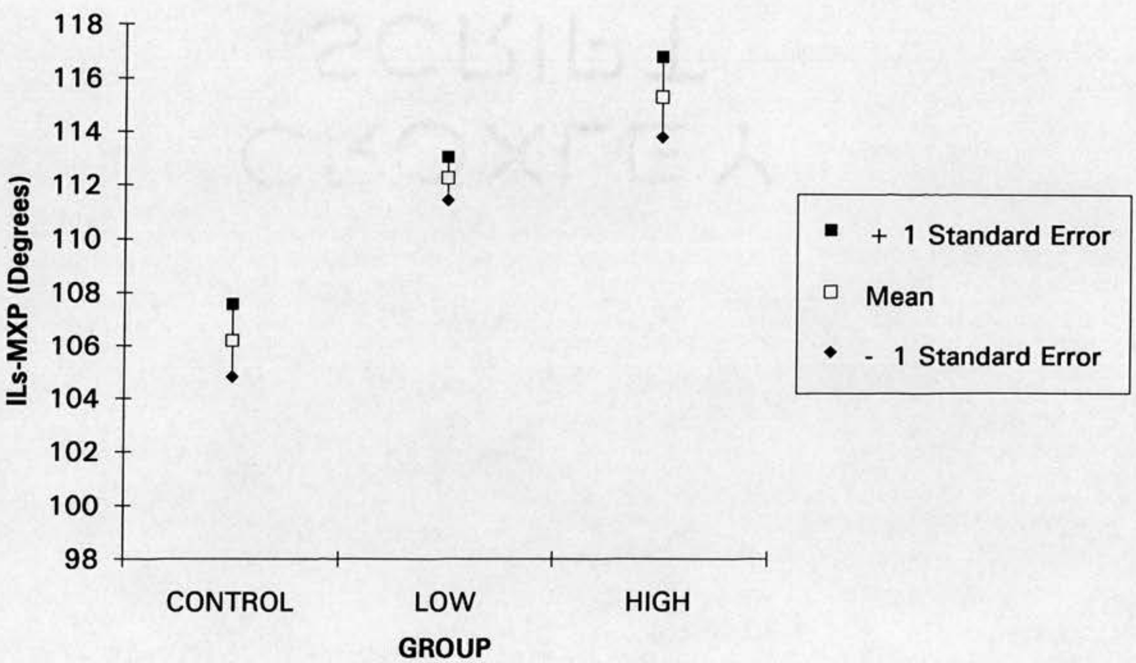
For example, when the angle between the maxillary incisor and the maxillary plane was investigated, the Study Group were found to have significantly higher values than the Control Group. When the same variable was investigated for the two sub-groups of the Study Group, the "High" Sub-group were found to have greater values than the "Low" Sub-group. The mean value for the "Low" Sub-group was therefore somewhere between the mean for the Control Group and the mean for the "High" Subgroup.

Such consistent trends were observed for the cephalometric variables ss-n-sm, $IL_s$-MXP, $IL_i$-$IL_s$, $IL_s$-SNL, pm-sp and MXP-SNL. Only the variable s-n-ss was found to show an opposite trend when Sub-groups were compared.

As an example, Figure 17 illustrates graphically the relationship between the two Sub-groups and the Control Group of non-digit suckers with respect to the variable $IL_s$-MXP. Similar trends were observed for ss-n-sm, $IL_i$-$IL_s$, $IL_s$-SNL, pm-sp and MXP-SNL.

Figure 17.

Graphical representation of the mean values of the variable $IL_s$-MXP for the Control Group and the two Sub-groups of the Study Group. Error Bars indicate +/- 1 standard error.



(iv) Study Model Variables.

(a) Quantitative variables.

It has already been demonstrated that for only two quantitative study model variables were significant differences observed between the Study Group and the Control Group. Intra-group comparisons were therefore made for these variables, namely Incisor Overjet and Maxillary Intercanine Width.

In a similar manner to the intra-group analysis of cephalometric variables, two stages of analysis were conducted.

Table 32 presents the results of the correlation analysis for the study model variables "Incisor Overjet" and "Maxillary Intercanine Width" with "Reported Hours of Digit Sucking per Day". The correlation coefficients were found to be very weak, and indeed neither correlation differed from zero to a statistically significant degree.

Table 33 presents the results of the comparison of mean values of "Overjet" and "Maxillary Intercanine Width" between the two Subgroups of the Study Group. The criteria for the two subgroups were as previously described.

Table 32.

Results of the correlation analysis for two study model variables correlated to the historical variable "Reported Hours Digit Sucking per Day".

| Variable | Pearson Correlation Coefficient (r) | t value | P value |
|---|---|---|---|
| Incisor Overjet | 0.21 | 1.392 | <0.5, >0.1 |
| Maxillary Intercanine Width | 0.07 | 0.455 | >0.5 |

Table 33.

Comparison of the mean value of 2 study model variables between the Low Duration and High Duration subgroups of the total Study Group. Linear variables are quoted in millimetres.

| Variable | "Low" Subgroup Mean | "High" Subgroup Mean | Difference Between Means | "t" Value | P Value |
|---|---|---|---|---|---|
| **Incisor Overjet** | 6.00 | **7.35** | -1.35 | **1.633** | 0.107 |
| **Maxillary Intercanine Width** | 31.34 | **31.96** | -0.62 | **0.547** | 0.597 |

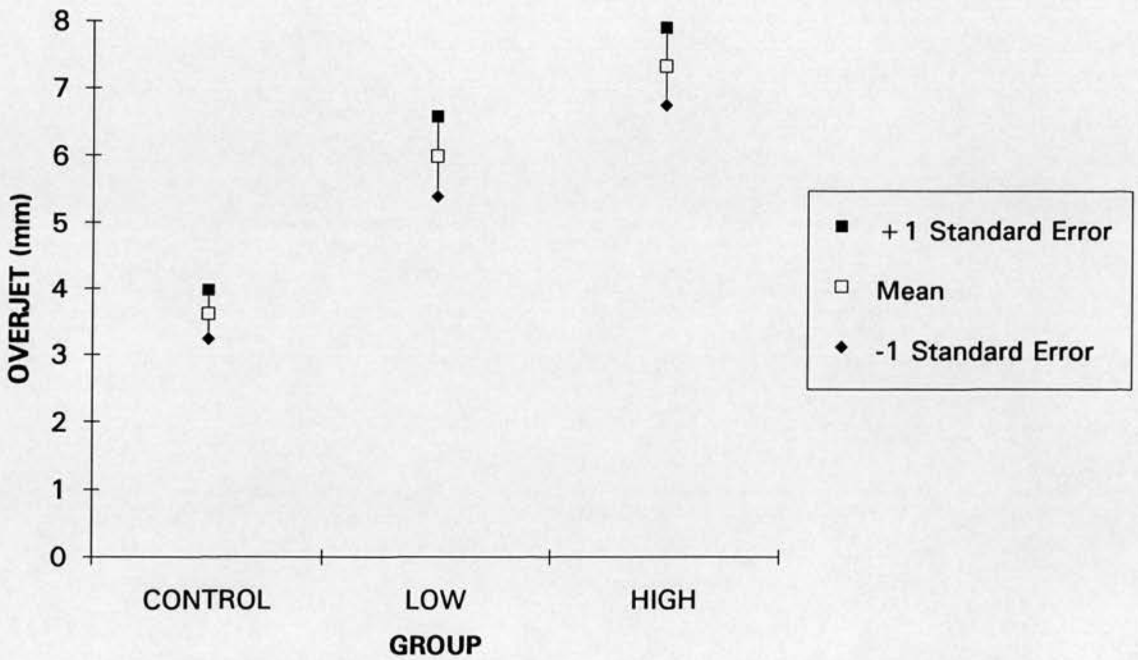
Neither of the comparisons of the means in Table 33 demonstrated differences which were statistically significant.

The data for Incisor Overjet showed that the Low Duration Subgroup mean value of 6.00mm was somewhere between the mean value for the Control Group (3.61mm) and the mean value for the High Duration Subgroup (7.35mm). Figure 18 illustrates the relationship graphically and suggests that a trend for increased overjet with increased duration of digit sucking may exist.

The data for Maxillary Intercanine Width shows that the mean value for the High Duration Subgroup was greater than that for the Low Duration Subgroup. This would appear to go against the trend observed when the Study Group was compared with the Control Group, when it was shown that the digit suckers had significantly reduced Maxillary Intercanine Widths. However the results for the Subgroup comparison may be somewhat artefactual due to the relatively small numbers of readings for this variable in the two subgroups (17 and 12 respectively)

Figure 18.

Graphical representation of the mean values of the variable Incisor Overjet for the control group and the two Sub-groups of the Study Group. Error bars indicate +/-1 standard error.



(b) Categorical variables.

Incisor Overbite. Distribution of the categories of Incisor Overbite has already been shown to be significantly different between the Study Group and the Control Group. To investigate the relationship further the Study Group was subdivided into two subgroups with respect to their reported hours digit sucking per day ( less than 6 hours = "Low Duration", 6 hours or more = "High Duration"). This subdivision enabled crosstabulation with the categorical variable "Incisor Overbite".

Table 34 illustrates the crosstabulation of the subgroups of the Study Group with the 6 categories of Incisor overbite as described in Chapter 5. The Chi Square test was not valid for the data in this form since more than one fifth of the cells had an "expected " value less than 5. As had been necessary for the similar comparison between the Study Group and the Control Group, the Incisor Overbite categories were then recoded into 3 categories. (1,2 and 3 = Open, 4 = Normal, 5 and 6 = "Deep")

Table 35 presents the crosstabulation of Subgroup with Recoded Incisor Overbite Category. With the data in this form the Chi Square test was found to be valid. The value of Chi Square was 0.31, Degrees of Freedom = 2. The corresponding value of "P" was 0.856. The null hypothesis that there was no difference in the distribution of Recoded Incisor Overbite Category between the two subgroups could not therefore be rejected.

Table 34.

Cross tabulation of "Incisor Overbite Category" with "Subgroup". Actual numbers are quoted.

| | | SUBGROUP | | |
|---|---|---|---|---|
| | | LOW DURATION | HIGH DURATION | Row Total |
| Overbite Category | 1 | 1 | 3 | 4 |
| | 2 | 2 | 5 | 7 |
| | 3 | 11 | 9 | 20 |
| | 4 | 5 | 4 | 9 |
| | 5 | 2 | 2 | 4 |
| | 6 | 0 | 0 | 0 |
| Column Totals | | 21 | 23 | 44 |

Table 35.

Cross tabulation of "Recoded Overbite Category" with "Subgroup". Actual numbers are quoted.

| | | SUBGROUP | | |
|---|---|---|---|---|
| | | LOW DURATION | HIGH DURATION | Row Total |
| Recoded Overbite Category | Open | 14 | 17 | 31 |
| | Normal | 5 | 4 | 9 |
| | Deep | 2 | 2 | 4 |
| Column Totals | | 21 | 23 | 44 |

Chi Square = 0.31

Degrees of freedom = 2

P value = 0.856

Buccal Crossbite. Analysis of buccal crossbite between the Study Group and the Control Group revealed a weak tendency towards greater prevalence of crossbite in the Study Group. However, such a small number of the Study Group demonstrated buccal crossbites (14 subjects) that further subdivision of the Study Group by variables such as duration of sucking was considered unlikely to produce meaningful results.

I.O.T.N. - D.H.C. Distribution of the Index of Orthodontic Treatment Need has already been demonstrated to have been very similar for both the Study Group and the Control Group. Further analysis for this variable for the Study Group alone was not therfore considered worthwhile.

# CHAPTER 8

# DISCUSSION

## A. Introduction.

Previous studies have investigated prevalence, aetiology, effects and treatment of digit sucking habits, often with special consideration towards the dentofacial region. This study has investigated two of these parameters, namely the prevalence and the effects of persistent digit sucking habits in patients referred to a Hospital Orthodontic Department.

## B. Methodology

### (i) Sample selection.

One of the aims of the study was to determine the percentage of new patients attending a Hospital Orthodontic Department who had a history of a persistent digit sucking habit at the time of the initial consultation. This was determined by simple enquiry at the time of examination, a practice which is routine at initial consultation. No attempt was made to identify the digit suckers by characteristics of their malocclusion, for doing so would have tended to weight the sample with digit suckers with the most extreme characteristics associated with the habit. All patients who stated that they still had a habit at the time of their examination were considered to be "persistent digit suckers".

For the investigation of the effects of digit sucking habits, a Study Group was identified. From the total number of persistent digit suckers (54), a small number were excluded from the study. 7 were excluded on grounds of age since they were under the age of 10 years. The age limit was imposed to remove the youngest outliers from the sample to avoid problems of co-operation, and to concentrate the study on subjects who were well into the mixed or permanent dentition stages of occlusal development. A further 3 subjects who would have qualified for entry into the Study Group were eliminated from the study at the beginning since they failed to return to the department after their initial consultation, preventing the collection of study models or radiographs. There is no evidence to suggest that the failure of these three subjects to return substantially altered the characteristics of the Study Group. In general, "refusers" in any study tend to be atypical of the population being studied and the possibility does exist that these 3 subjects perceived their own problem to be of too little significance to necessitate returning to the department. If indeed these subjects all had uncharacteristically mild effects of digit sucking then it is possible that in the analysis of mean values, the Study Group results were slightly biased in the direction of being more severe. This hypothesis is impossible to test with the data available, although in reality if such an effect did exist it is likely to be very weak in view of the small number of cases who failed their appointments (3) relative to the larger number of cases in the Study Group (44).

The final Study Group consisted of 44 consecutive cases, who were 10 years or older, who were persistent digit suckers and who were referred to the Orthodontic Department of Victoria Hospital. There is no reason to believe that the sample was not typical of the population of patients who fulfil this description.

(ii) Control Group Selection.

When conducting an observational study of the effects of an anomaly upon a group of patients, it is common practice to compare the anomaly group with a similar group who do not have the anomaly. In this study, the "anomaly group" were patients who had been referred to an orthodontic department and who also had a persisting digit sucking habit. To compare this group with a control group of cases with "ideal" characteristics would have made it impossible to identify whether any differences observed could be attributed to the digit sucking or were related to the fact that they were referred patients. To avoid this problem, the Control Group for this study was drawn from the same population of referred patients as the Study Group, the only difference being that the Control Group did not have persistent digit sucking habits. In doing this it was possible to test whether the cephalometric and study model variables for the digit sucking group differed significantly from the typical values for patients referred to the department. Furthermore it was possible to address the final aim of the study which was to test the hypothesis that digit suckers referred to the department present with a higher than typical orthodontic treatment need.

It is important to recognise that the Control Group were in fact not "normal" in that they were all referred patients, whom had presumably been identified by the referring practitioner as having an orthodontic problem. The results of the comparison between the Study Group and the Control Group may therefore be interpreted as showing the effect of the persistent sucking upon the dentofacial region over and above the other effects to which both the Study Group and the Control Group were exposed.

In selecting the Control Group, every effort was made to ensure that they came from the same population as the Study Group, and the cases were selected such that the age and sex distribution was the same as the Study Group. This was necessary since a truly random sample of the referred patients would probably have had a different age distribution to that of the digit suckers, who were all in the 10 to 16 years age range. Also, and in common with other studies into digit sucking, females represented a significantly larger proportion of the Study Group than males. Matching the age and sex distribution of the Control Group to that of the Study Group was adopted as a means of eliminating these determinants of dentofacial growth from the comparison of the two groups.

Patients were allocated to the Control group by identifying subjects of suitable age and sex from the clinic list before their consultation, such that the group was a truly representative sample of non digit sucking new patients. Interestingly, 2 cases selected from the clinic list were subsequently found to have persisting digit sucking habits and were included in the Study Group.

1 patient selected for the Control Group in this manner declined to enter the study, and a further patient was not considered to require a cephalometric lateral skull radiograph for the full assessment of their problem. It is possible that the exclusion of these two cases altered the characteristics of the Control Group, but as these were the only two out of the total number of cases chosen from the clinic lists, it seems unlikely that this effect was substantial. The Control Group was considered to consist of a typical sample of referred patients, without persistent digit sucking habits and with the age and sex distribution as determined by the Study Group.

(iii) Cephalometric Analysis.

Standardised cephalometric lateral skull radiographs were used for the measurement of 19 vertical and anteroposterior craniofacial variables. Uniformity of magnification was verified by measurement of the image on each radiograph of a ruler held in the clinical mid sagittal plane, and no significant difference in magnification was observed between the two groups.

The variables were measured by tracing the relevant anatomical landmarks onto acetate and then using a computerised analysis system, The Dentofacial Planner. 35 anatomical landmarks were marked onto the tracing and digitised to enable The Dentofacial Planner to calculate the 19 variables. Gross operator errors, such as incorrect sequence of digitising, were eliminated by plotting out a 1:1 image of the digitised tracing and comparing this with the original radiograph.

Eriksen and Solow (1991) demonstrated that lack of linearity is a common feature with digitising tablets, such that digitising a given object in different positions on the tablet will lead to different measurements for the same object. In this study, a standard template was digitised in 16 different loci on the digitising tablet, and the degree of error in each position calculated, to identify the region of least linear distortion. Although determined in a simple manner, the result of this test was convincing and suggested that the most central area of the digitiser had the least linear distortion.

The combined effect of machine errors and errors associated with landmark identification were assessed using a duplicate measurement technique for 12 radiographs. The parameters used to assess error were the Mean Error, Error Standard Deviation, Method Error and the 95% Confidence Limit for Error. In terms of both magnitude of error and relative susceptibility to error the 19 variables determined in this study were found to compare well with published standards for the technique (Sandler 1988, Gravely and Benzies 1974). The cephalometric analysis conducted in this study was therefore concluded to be valid and repeatable to an acceptable degree. The Dentofacial Planner was found to be an exceptionally versatile measurement tool, which facilitated user determined cephalometric analyses with relatively easy programming.

(iv) Study Model Analysis.

A range of vertical, anteroposterior and transverse variables, together with the Index of Orthodontic Treatment Need were determined from orthodontic study models. In a similar way to the cephalometric analysis, method errors were checked by conducting a duplicate assessment for the 6 quantitative and 3 categorical study model variables.

For the quantitative variables errors were found to be small. To place the error in context, the Method Error (s) parameter for any variable may be expressed as a percentage of the mean value for that variable. Considering the Maxillary and Mandibular Intermolar and Intercanine Widths, the Method Error represented less than 1% of the mean value of each variable. For Palatal Vault Depth, the corresponding figure was 1.5% and for Incisor Overjet 4.3%. The reason for Incisor Overjet appearing to have the worst degree of error is that the unit of measurement is large relative to the mean dimension. Despite this, the errors observed for the study model quantitative variables were considered to be within acceptable limits.

For the categorical variables, the Kappa statistic was used to assess repeatability. All 3 variables were observed to have an "almost perfect" strength of agreement between the first and second assessment. The results for the repeatability of categorical variables were similar to previously published studies (Holmes 1992, Brook and Shaw 1989) and were considered to be within acceptable limits.

In summary, all the measurement techniques adopted in this study were tested for repeatability, and all were found to be within acceptable limits of error relative to similar studies published elsewhere. Furthermore, since the techniques used for the Study Group and the Control Group were identical, the levels and degree of error can be expected to be consistent throughout.

(v) Statistical manipulation and analysis.

Data analysis was conducted using a computerised system designed by the World Health Organisation and the Centre for Disease Control for medical research. All the methods used were those considered appropriate to each individual analysis, and a full breakdown of the methods and formulae utilised is given in Appendix A.

C. Results of historical enquiry.

(i) Prevalence of digit sucking in new patient referrals.

New patients attending a Hospital Orthodontic Department generally present with a wide range of clinical problems, of which digit sucking habits constitute but one. In this study, 54 out of 885 (6.1%) new patients were found to have a persistent digit sucking habit at the time of their initial consultation. It is impossible to know from the data available how many of these patients would not have required to be referred had they not got a digit sucking habit. It seems likely that a number of the patients would have developed malocclusion for other reasons, such as genetic factors, dental caries or trauma. However, 6.1% remains a substantial group of cases exhibiting a particular problem. The Hospital Orthodontic Service in Fife conducted a total of 2419 new patient consultations in the year to 31-3-93, and if the 6.1% figure is extrapolated to this it would constitute 147 patients. Clearly for a single clinical problem this represents a substantial demand for increasingly stretched resources.

(ii) Age and sex distribution.

Of the 54 cases with habits, all but one were 6 years or older. Using the terminology of Larsson and Dahlin (1985) the great majority of the cases were "prolonged digit suckers" rather than "initial digit suckers". For a referred population, this is appropriate and as would be expected, since the contemporary opinion on the treatment of habits is that no treatment is indicated for initial habits. The ages of patients with habits conformed well to the Normal Distribution, with a mean value of 11.4 years and a range from 5 to 16 years. The distribution probably resulted from the interaction of two factors, firstly an increasing need for intervention with increasing age, and secondly a decrease in total prevalence of digit sucking with increasing age.

Females accounted for 66% of cases and this is in line with many other prevalence studies which have demonstrated a higher prevalence of digit sucking in females. This study investigated a referred population, and it is possible that the Female:Male ratio of 2:1 resulted from greater demand for referral from the females. However, 2:1 was the ratio reported in Baalack and Frisk's 1971 survey of 12 year old school children, and it seems highly likely that the distribution of sex among the referred patients investigated in this study reflects well a sex difference in the prevalence of digit sucking among the general population. The result for this study is therefore in agreement with the consensus of contemporary opinion.

(iii) Reported method of digit sucking.

A wide range of different methods of digit sucking were reported, although almost 90% identified the thumb as the digit most often sucked. While it might have been expected that the habits would be associated with a particular digit, 18% indicated that they varied the hand which was sucked. When the data on which digit, which hand and which surface uppermost were combined, 3 distinct patterns were identified (Figure 11, 12 and 13) into which all cases could be placed. As might have been expected, almost 90% habitually sucked a thumb with the palmar surface uppermost. Habits involving fingers, either palmar or dorsal surface uppermost were observed in much smaller numbers. It has been postulated that modes of sucking involving the palmar surface uppermost are most detrimental to the dentition in view of the extended lever action upon the teeth. Unfortunately in this study the number of cases with alternative sucking methods was too small to enable a meaningful comparison of methods.

(iv) Reported daily duration of sucking.

Without conducting a formal monitoring study it is difficult to attribute an index of intensity of a sucking habit to a particular individual. In this study the parameter of "Reported Hours Digit Sucking per Day" was used as an index of the intensity of individual habits. Patients were asked to estimate to the best of their ability the number of hours per day that the digit was in their mouth. Responses ranged from 1 to 20 hours, median 6 hours. Although these absolute figures are of limited interest they did enable some form of subdivision of the digit suckers into those with mild intensity and those with high intensity habits, which in turn enabled evaluation of dose related effects of the habits on the dentofacial and occlusal variables. The skewed distribution of the responses to this enquiry indicated that the majority of cases had relatively few hours of sucking per day, but a smaller number reported unusually high intensity.

(v) Associations.

Responses to enquiry into associated habits and particular times of day when digit sucking was a problem were all very similar. No reports of associated habits were recorded, and the vast majority of patients reported that they were most aware of their habit either when they were tired or at night. A common theme was the observation that digit sucking was often an aid to falling asleep at night.

D. Intragroup comparison of historical data.

Considering the Study Group alone, it was possible to investigate the relationship between different historical variables. Of particular interest was the observation that the mean reported hours of digit sucking per day increased with increasing age, and that this correlation was statistically significant at the 5% level. On face value this relationship would appear to be contrary to expectations, for previous studies have demonstrated a reduction in digit sucking with age. However this study investigated referred patients, rather than being of cross-sectional design. The most likely explanation for the increase in mean reported hours sucking per day with age is that as age increases, children with weaker habits progressively cease of their own accord, leaving only the children with the most persistent and deeply established habits. If this relationship is real then reported hours digit sucking per day may be a useful crude index of how likely a child is to give up a habit spontaneously, giving the clinician the opportunity to prioritise aversion therapy. This observation is worthy of deeper investigation in future studies.

Reported hours digit sucking per day was compared between the sexes, and the difference was found to be not statistically significant. Males had a mean value of 7.8 hours per day, 1.9 hours greater than the corresponding figure for females ($P = 0.063$). Rather than being a true sex difference, this observation may in fact be an expression of age differences between the sexes, for the males had a mean age of 12.4 years, compared to the females of 11.6 years, and mean reported hours of sucking has been shown to be significantly related to age.

E. Cephalometric analysis of craniofacial morphology.

(i) Introduction.

A total of 19 variables were measured from cephalometric lateral skull radiographs, and comparison made between the results for the Study Group and the Control Group. 6 variables were significantly different at the 1% level, while 1 other was significantly different at the 5% level. The analysis was designed to measure vertical and anteroposterior variables, both of a localised dental and more generalised skeletal nature. Few comprehensive cephalometric studies of digit sucking individuals have been published, but the results of the present study allow comparison with a similar study conducted by Larsson (1972). Larsson's study was of 9 year old children in Sweden, and he compared cephalometric features of 116 digit sucking children with 100 who had no history of a habit. For convenience, the results will be discussed in logical groupings.

(ii) Measures of prognathism.

The Study Group was found to exhibit a significantly increased degree of maxillary prognathism as measured by the variable s-n-ss, often known as SNA. The results of $83.668^{o}$ for the Study Group and $80.925^{o}$ for the Control Group were almost identical to those of Larsson (1972). It seems highly improbable that digit sucking has any substantial influence on the position of cephalometric points Sella and Nasion, since these points are particularly remote from the site of the habit. The most reasonable explanation of the increased maxillary prognathism is that digit sucking brings about an anterior growth displacement of the A point ( subspinale). This might be expected in view of the anterior force exerted on the anterior maxillary alveolar process during digit sucking.

In marked contrast, no significant difference between the digit suckers and the controls was observed for mandibular prognathism as measured by the variable s-n-sm, and again this was consistent with the findings of Larsson (1972). It seems likely that the anteroposterior forces generated during the act of digit sucking are more significant for the maxillary alveolar process than for the mandibular process.

Relative prognathism measured by the variable ss-n-sm was significantly greater for the Study Group than the Control Group, and reflects the increase in maxillary prognathism at the same time as no change in mandibular prognathism.

In general terms, these results suggest that patients with persistent digit sucking habits are more likely to present with a Class 2 skeletal base relationships than patients without such habits, and that these class 2 skeletal bases result from increased maxillary prognathism.

(iii) Incisor angular measurements.

The Study Group was observed to have maxillary incisors which were significantly more proclined than the Control Group when measured relative to the anterior cranial base and also relative to the maxillary plane. This effect was substantial, accounting for a difference of $9.39^{o}$ for $IL_s$-SNL and $7.74^{o}$ for $IL_s$-MXP, and probably resulted from the anterior force of digit sucking tipping the maxillary incisors in a labial direction. In contrast to this, the mean angulation of the mandibular incisors relative to the mandibular plane was not significantly different for the two groups. In Chapter 2 it was reported that previous authors have varied in their opinion regarding the effect of habits on mandibular incisor angulation,with some stating that proclination occurs and some stating that retroclination occurs. Although there was no significant difference in the mean value between the groups, the standard deviation for the digit suckers was somewhat larger than the controls, suggesting that there was more variation in mandibular incisor angulation in the digit sucking group.

As would be anticipated, with more proclined maxillary incisors, and unchanged mandibular incisors the Study Group were found to have a significantly decreased interincisal angle ($IL_s$-$IL_i$).

The findings on anteroposterior incisor angulation were entirely consistent with those of Larsson (1972). The findings support the view that digit sucking brings about the proclination of maxillary incisors and has a variable effect on the mandibular incisors.

(iv) Maxillary and mandibular plane relationships.

The angle between the maxillary and mandibular planes is often quoted in the analysis of an orthodontic case, because of the importance of the variable as a measurement of the vertical dimension. In general, high "MM" angles are associated with anterior open bites and long face while low values are associated with deep bites and short faces. Digit suckers are often reported to demonstrate anterior open bites, and the possibility exists that these are related to high maxillary mandibular plane angles. In the present study no significant difference was observed in the size of the maxillary mandibular plane angle (variable MXP-MNP) between the Study Group and the Control Group. This would suggest that any tendency towards anterior open bite in the digit sucking group resulted from localised dentoalveolar effects rather than by influencing the vertical skeletal relationship.

As might have been expected, no significant difference in the angulation of the mandibular plane to the anterior cranial base was observed. Of particular interest, however, was the observation that the angle of the maxillary plane relative to the cranial base was altered in the digit sucking group, and this finding was significant at the 5% level. The variable MXP-SNL was 5.723° in the Study Group and 7.382° in the Control Group, indicating the presence of a rotation of the maxillary plane, upwards anteriorly and downwards posteriorly. The presence of such a rotation was confirmed by the observation that the measurement of upper anterior face height (n-sp) was smaller in the digit suckers than the controls and the upper posterior face height measurement (s-pm) was larger in the digit suckers than the controls. Neither of these two differences achieved statistical significance, but they are important in that in combination they did represent a significant change in maxillary plane angulation. These results are entirely in agreement with those of Larsson (1972). While it is reasonable to assume that the presence of a digit in the mouth may offer some resistance to the downward growth of the anterior maxilla, the effect on the posterior end of the maxillary plane is less simple to explain. It is possible that the downward displacement of the posterior edge of the hard palate results from the generation of suction in the region of the posterior palatal vault during digit sucking. It is also possible that the downward displacement of the mandible which must occur for a digit to be placed between the teeth results in alteration in the stretch of the palatoglossus muscles and mucosa, leading to a downward force component. Such theories are speculative and with the present data it is only possible to suggest that digit sucking is probably associated with a downward displacement of the posterior aspect of the hard palate in combination with an upward displacement of the anterior maxilla. This remains an interesting topic for future study.

(v) Maxillary and mandibular lengths.

A highly significant difference was observed in the length of the maxilla from the anterior nasal spine to the posterior nasal spine, with the mean value for the Study Group being 55.007mm, 2.625mm longer than the corresponding figure for the Control Group. The reason for this apparent lengthening of the maxilla is likely to be as a result of the anterior force exerted on the anterior maxillary alveolar process by the digit during sucking. It would seem reasonable to assume that the increase in maxillary length, the increase in maxillary prognathism and the increase in maxillary incisor proclination are all related observations. The data available from this study is insufficient to identify whether any lengthening of the maxilla occurred in a posterior direction, but this seems unlikely in view of the position of the digit during normal sucking. In contrast, no significant difference in the length of the mandible was observed between the two groups. This further supports the observation that the influence of digit sucking on the mandibular structures is much less substantial than the influence on maxillary structures.

(vi) Cranial base measurements.

Three measurements were made involving cranial base structures, and all three showed no significant difference between the Study Group and the Control Group. Indeed for two measurements, posterior cranial base length and cranial base angle the mean values for the two group were almost identical. These observations are entirely as would be expected, considering that the two groups were matched for age and sex and the anomaly differentiating them was relatively distant from the cranial base. The close similarity in the length of the anterior cranial base does, however, support the validity of the control group in terms of the stage of dentofacial growth, for growth of this dimension continues throughout the pubertal growth spurt.

(vii) Vertical Face Height Measurements.

As already discussed, upper posterior face height and upper anterior face height showed differences between the groups which did not on themselves reach any conventional level of statistical significance, yet when taken together these differences did appear to be part of a significant rotation of the maxillary plane.

Two other measurements of face height were made, namely lower anterior face height and total anterior face height. Neither of these measurements demonstrated a significant difference between the groups. This further supports the observation that digit suckers who develop anterior open bites are demonstrating dentoalveolar modification, rather than any substantial skeletal change being responsible for the anterior open bite. As was expected with the absolute measurements already described, when the face height ratio was calculated for the two groups no significant difference was observed.

(viii) Summary of cephalometric observations.

When all the vertical and anteroposterior cephalometric variables were considered, it was clear that the digit sucking group showed a number of important differences from the controls. The differences were mainly dentoalveolar, and were restricted to the maxillary arch. Two notable skeletal differences were observed, namely an increase in maxillary prognathism and a rotation of the maxillary plane. In addition the increase in maxillary prognathism was associated with an increase in maxillary base length. Important negative observations were made in that the mandibular incisors appear on average to be unaltered by digit sucking although a wider range of mandibular incisor angulation was observed in the digit sucking group. Digit sucking also appeared to have very little if any impact on face height variables.

F. Intragroup comparison for cephalometric variables.

Unfortunately, although three types of digit sucking pattern were identified in the historical enquiry, the numbers involved in two of the types made meaningful investigation of the relative effects of the different types of sucking impossible. However an attempt was made to investigate whether the observed differences between the Study Group and the Control Group were dose related to the intensity of the habit. For these investigations the variable "reported hours digit sucking per day" was used as an index of the intensity of each individual's habit.

In the interpretation of these analyses an important point is that it has already been observed that the reported hours of digit sucking per day was significantly related to age. In investigating the relationship between a cephalometric variable and reported hours of digit sucking per day, it is possible that age related changes could act as confounders to meaningful results.

For each of the 7 cephalometric variables which demonstrated significantly different results between the two groups, Pearson correlation coefficients were determined with respect to reported hours of digit sucking. These calculations failed to achieve any conventional level of statistical significance. This may well have been a consequence of a wide range of individual variation, or could be related to the fact that the cephalometric variables were a record of past sucking habits and the reported hours digit sucking was a measure of present habit activity.

In an attempt to conduct a less specific statistical test, the Study Group was divided into two almost equal Subgroups, the Low Duration Subgroup who reported sucking 5 hours or less per day and the High Duration Subgroup who reported sucking more than 5 hours per day. The Student's t test failed to demonstrate any significant differences between the subgroups for the 7 variables under investigation. An important observation was made that for all but 1 variable, the Low Subgroup mean value lay somewhere between the High Duration Subgroup value and the Control Group value. This was interpreted as indicating that dose related effects do probably exist, but that the number of subjects in the Study Group was insufficient to demonstrate this in a statistically convincingly manner. Furthermore it is probable that the variable "Reported Hours Digit Sucking per Day" is too weak a measure of previous digit sucking intensity for correlation with effects which have presumably accumulated over a prolonged period.

G. Dental and occlusal analysis of study models.

(i) Introduction.

In this study, standard orthodontic study models of the Study Group and the Control Group were measured to allow comparison of a total of 9 variables. All the models were cast from impressions taken before any intervention was made and thus represented the presenting occlusal characteristics of both the Study Group and the Control Group.

The occlusal analysis undertaken was designed to complement the cephalometric analysis by measuring 5 transverse dimensions (none of which could be determined from cephalometric lateral skull radiographs), 2 vertical characteristics and 1 anteroposterior characteristic. In addition the study models were used to evaluate the Index of Orthodontic Treatment Need (Dental Health Component), to allow comparison of the relative treatment needs of the two groups. Each of these groupings will be considered in turn.

(ii) Transverse variables.

4 quantitative transverse variables were determined, namely Maxillary Intermolar and Intercanine Width and Mandibular Intermolar and Intercanine Width. Of these, only Maxillary Intercanine Width showed a statistically significant difference between the two groups. For this variable, the mean value for the Study Group was 31.70mm, some 1.74mm less than the corresponding figure for the Control Group. The remaining three variables in this group failed to achieve statistically significant differences, although some interesting and important trends were observed. Maxillary Intermolar Width was reduced in the digit sucking group, although not to the same extent as Maxillary Intercanine Width. In contrast, both the mandibular transverse measurements were observed to be larger for the digit sucking group.

These results are largely consistent with those of Larsson

(1972) who measured intermolar widths of 9 year olds and found no significant difference for digit suckers. Bowden (1966) and Ruttle (1953) were also unable to demonstrate any difference in intermolar width of digit sucking children. Studies of younger children have demonstrated that digit and/or dummy sucking habits are associated with reduced maxillary intercanine widths. (Lindner and Modeer 1989, Larsson 1990). Combining the results of the present study with previously published work, it seems reasonable to postulate that digit sucking habits persisting into the period of the permanent dentition do exert some transverse effect, which is expressed most substantially in the maxillary intercanine region. The theory that digit sucking involves the displacement of the tongue in an inferior direction, resulting in reduced transvere support of the maxillary arch and increased transverse pressure on the mandibular arch was postulated by Larsson (1987). The results of the present study are entirely consistent with Larsson's view, and also support the view that any transverse effects which are created by digit sucking are maximal in anterior regions and minimal in posterior regions of the mouth.

In addition to the quantitative variables already discussed, the study models were assessed for the presence of buccal segment crossbite, which was recorded as a categorical variable with 5 well defined categories. The 2x5 contingency table which resulted was unsuitable for statistical analysis by the Chi square method for it failed to achieve all the criteria set down by Cochran (1954), and so it was necessary to recode the data into just 2 categories of crossbite- "present" or "absent". 32% of the Study Group had a crossbite of some form, while 68% did not. The corresponding figures for the Control Group were 14% and 86% respectively. The increased prevalence of crossbite observed in the Study Group was analysed using a 2x2 contingency table and the Chi square method, and while the uncorrected Chi square result indicated a significant difference between the 2 groups, the Yates corrected Chi square value (which is preferred for 2x2 tables) indicated a P value of 0.075. While this is close to the conventional level of significance of 0.05, and does suggest that a probable relationship between digit sucking and crossbite existed, it is not possible to discount the possibility that the difference in distribution resulted by chance alone. The null hypothesis of there being no difference in the prevalence of posterior crossbite in persistent digit suckers cannot be rejected.

This result is interesting in that it supports the observation of Larsson (1983b), who found that there was not an elevated prevalence of posterior crossbite among 10 year olds with persistent habits compared to non habit controls. The theory that digit sucking only exerts a transverse influence as far distally as the distal aspect of the second deciduous molar or premolar was promoted by that author. The finding is, however, at variance with the opinions of Martinez and Hunckler (1986), Hannuksela and Vaananen (1989), Popovich (1966) and Willmot (1984). It seems likely that an unequivocal proof of the lack of any relationship between digit sucking and posterior crossbite could only be possible with larger studies than the present one.

(iii) Vertical variables.

Anterior open bite is an occlusal feature which is often attributed to digit sucking habits. In this study, overbite status of the two groups was assessed on a categorical basis, with overbite/openbite placed in 1 of 6 categories for each patient. 3 of the categories described bites progressively more "open" than normal, and 2 described bites deeper than normal, with the remaining category indicating normal overbite.

When the results of the incisor overbite assessment for the 2 groups were tabulated in a 2x6 contingency table, it became clear that although a substantial difference in the distribution of categories existed between the two groups, the Chi square method would be unsuitable for the data in that form. The data was therefore recoded into just three categories of "Open Bite", "Normal Overbite" and "Deep Bite". In this form the data was suitable for the Chi square method, and indeed a highly significant difference in distribution of the overbite categories was observed.

This data confirms the almost universal observation that digit sucking habits are associated with greater prevalence of anterior open bite. Taken in conjunction with the previously discussed observation from the cephalometric analysis that there was no difference in the maxillary mandibular plane angle, and no difference in the anterior face height measurements, this data supports the view tht the anterior open bite observed in persistent digit suckers is purely dentoalveolar in nature, and does not result from significant alteration of the vertical skeletal jaw relationships.

Palatal Vault Depth was determined in this study by measuring the perpendicular distance from the line joining the mesiopalatal cusps of the first permanent molars to the midline palatal raphe. The results were observed to be very similar for both the Study Group and the Control Group, in agreement with the findings of Larsson (1972), but at variance with the findings of Hanson and Cohen (1973). The assertion by some authors that digit sucking is associated with deep palates would appear to be doubtful.

(iv) Anteroposterior variable.

Only one anteroposterior variable was determined from the study models, and this was the incisor overjet. The mean result for the Study Group was 6.7mm, greatly increased when compared to the corresponding figure of 3.61mm for the Control Group. This relationship achieved a very high level of statistical significance, and supports the observation made from the results of the cephalometric analysis that digit sucking is associated with a proclination of the maxillary incisors. This is entirely as would be expected in such a group as was investigated in this study, and is wholly consistent with the consensus view in this respect.

(v) Index of Orthodontic Treatment Need.

One of the aims of this study was to test the hypothesis that persistent digit suckers present to Hospital Orthodontic Departments with a higher level of treatment need than do non digit suckers. To evaluate this, the Index of Orthodontic Treatment Need was determined from the study models of each group. Very similar distributions were observed for both the Study Group and the Control Group, and indeed no significant difference was detectable. The hypothesis that digit suckers present with a higher treatment need was therefore rejected.

The results of this study are not able to identify whether persistent digit sucking elevated the orthodontic treatment need of the subjects found to have such habits, for it will never be known what Index of Orthodontic Treatment Need they would have achieved without the habits. The only way to evaluate this fully would be to conduct a large longitudinal study following a sample identified at birth as being similar in as many respects as possible and then comparing the outcome in terms of I.O.T.N. for groups who subsequently develop habits and those who do not. It seems likely from the present study, however, that since digit sucking has been shown to be significantly related to incisor overjet, and this is an important determinant of I.O.T.N., that the presence of digit sucking in the Study Group was responsible to some degree for the elevation of the Index of Orthodontic Treatment Need to a level seen in typical referrals to the Hospital Orthodontic Service.

H. Intragroup comparison of study model analysis.

As was previously discussed, the only valuable criterion by which intragroup comparison of variables could be made was the reported hours of digit sucking per day. Two of the study model variables were noted to show significant differences between the Study Group and the Control Group, namely Incisor Overjet and Maxillary Intercanine Width. These were therefore analysed to investigate whether the effect of digit sucking was dose related.

Firstly, Pearson Correlation Coefficients were determined for hours of digit sucking per day and each of the above mentioned variables. For both cases the correlation was found to be very weak, and did not achieve statistical significance. In a similar manner to the intragroup analysis of the cephalometric variables, the Study Group was then divided into two equally sized subgroups, the Low Duration Subgroup who reported sucking 5 hours or less per day and the High Duration Subgroup who reported sucking 6 hours or more per day. The mean value of the Incisor Overjet and the Maxillary Intercanine Width was determined for each of the subgroups, and Student's t tests conducted to investigate the differences in the means. For neither variable did the difference in the means achieve statistical significance, although the data for Incisor Overjet showed an interesting trend. It was noted that the mean value for the Low duration Subgroup of digit suckers fell someway between the value for the Control group and the value for the High Duration Subgroup. Although the trend did not achieve statistical significance, and so must be viewed with a great deal of caution, it would tend to suggest that a degree of dose related effect exists. In contrast to this, the findings for Maxillary Intercanine Width are harder to explain, since the value for the Low Duration Subgroup showed more difference from the Control Group than did the High Duration Subgroup. This is the reverse of what might have been expected if Maxillary Intercanine Width was in some degree related to the level of digit sucking as measured by the reported hours of digit sucking per day. A number of possible explanations exist for this apparent anomaly. Firstly, since a number of the digit sucking group did not have both maxillary permanent canine teeth erupted at the time of examination, only 29 measurements of Maxillary Intercanine Width were available for the Study Group in total. Secondly, the younger members of the Study Group were over-represented in the Low Duration Subgroup (as already discussed, Reported Hours of Sucking was significantly related to age). The younger members of the Study Group were also those least likely to have both maxillary permanent canine teeth present at the time of examination. The means for Maxillary Intercanine Width for each of the subgoups were probably substantially biased by these factors.

Of the categorical study model variables, only Incisor Overbite demonstrated a significant difference between the Study Group and the Control Group. The distribution of the Recoded Incisor Overbite category (Open, normal or deep) was compared using the Chi square test. No significant distribution was observed between the two subgroups and the null hypothesis that there was no difference in the distribution could not be rejected.

It is perhaps surprising that the analysis of the possible dose related effect of digit sucking carried out in this study failed to produce any statistically significant results, particularly for those variables such as Incisor Overjet and $IL_s$-MXP which were found to have exceptionally high levels of statistical significance when digit suckers were compared to non digit suckers. It has only been possible to demonstrate trends towards possible dose related effects. Probably the most important factor in this respect is that "Reported Hours of Digit Sucking per Day" is too weak an index of "dose" of digit sucking. Even if the patients were entirely accurate in their estimations of their hour of sucking per day, this variable takes no account of previous exposure, and it is likely that the observed dentofacial changes are more related to years of accumulated habit rather than the intensity at one moment in time. The results of this study neither confirm nor refute the presence of dose related effect of digit sucking, but demonstrate that identification of a valid index of "dose" which takes account of previous exposure as well as current exposure would be essential if meaningful data on dose effect was to be produced.

# CHAPTER 9

# CONCLUSIONS

A. Findings of the present study.

1. Patients with persistent digit sucking habits represent a substantial proportion of new patients attending a Hospital Orthodontic Service, with females outnumbering males by 2 to 1. The age of such patients was found to range from 5 to 16 years.

2. Three distinct methods of digit sucking were observed, but the huge majority of patients reported a method involving a thumb, positioned palmar surface uppermost.

3. Most persistent digit suckers reported sucking for only a few hours per day, but a small number reported sucking more than half of the day. The variable Reported Hours of Digit Sucking per Day was found to be positively and significantly correlated with age, and may offer a means of identifying which persistent suckers will continue into their later teenage years.

4. Persistent digit sucking was found to be associated with identifiable craniofacial and occlusal characteristics.

5. Persistent digit sucking habits were found to be

significantly associated with increased maxillary prognathism, increased relative prognathism, increased maxillary incisor proclination, reduced interincisal angulation, increased maxillary anteroposterior length and a rotation of the maxillary plane in an upward direction anteriorly and downward direction posteriorly.

6. No significant associations were observed between persistent digit sucking and mandibular prognathism, cranial base structures, maxillary-mandibular plane angulation, mandibular incisor proclination, nor any of the measures of anterior face height.

7. Persistent digit sucking habits were found to be significantly associated with reduced maxillary intercanine width, increased incisor overjet and reduced incisor overbite.

8. No significant associations were observed between persistent digit sucking and maxillary intermolar width, mandibular intercanine width, mandibular intermolar width, buccal crossbite prevalence and palatal vault depth.

9. The data collected in this study was unable to confirm or refute any possible relationship between the degree of exposure to digit sucking and the degree of alteration of craniofacial characteristics. Such a relationship appears to be likely.

10. Persistent digit suckers presented with very similar

levels of orthodontic treatment need as non digit suckers. The possibility remains that it was the presence of their persistent habit which brought these patients up to a threshold of orthodontic treatment need which triggered their referral, and that without their habits their level of orthodontic treatment need would not have warrented referral to a specialist service.

B. Possibilities for future research.

A number of issues have become apparent during the course of the present study which may prove to be of interest in future studies.

The reported hours of digit sucking per day, which was found to be an extremely simple parameter to determine, appeared to have some potential as a means of identifying cases likely to continue digit sucking the longest. A full evaluation of the validity and application of such an index would provide a useful diagnostic aid for prioritising aversion appliance therapy.

It would seem likely that the prevalence of digit suckers will vary in different Hospital Orthodontic Departments. The prevalence data in this study provides a baseline for future comparison with similar studies elsewhere. Of particular interest would be whether prevalence at Hospital Orthodontic Departments varied with socio-economic background of the catchment area for the hospital. There would be considerable value in collecting data on dummy sucking in any investigation into digit sucking , as these two habits do appear to be linked. In view of the significant detrimental effects that digit sucking has been shown to exert on the dental occlusion, the possible advantages of promoting the use of dummy as a preventive measure deserve serious consideration.

The present study has identified three modes of digit sucking which may have different influences upon the occlusion and dentofacial growth. It would be of interest to compare the effects of the three different modes if sufficient numbers of the two least frequent modes could be collected.

Many of the effects of digit sucking observed in the present study have been reported elsewhere. Despite this, it is difficult to confidently explain the observation that the posterior end of the maxillary plane appears to be displaced in an inferior direction in persistent digit suckers. Further investigation into muscle activity and intra oral pressures during sucking may provide an explanation for this observation. There also remains some uncertainty as to whether digit sucking habits are responsible for buccal crossbites in the permanent dentition. The present study suggested a trend towards such a relationship, but this failed to achieve statistical significance. A similar study, but with larger numbers may provide a more unequivocal answer to this problem.

Investigation of orthodontic treatment need among digit suckers would be of greatest value if conducted in a prospective, longitudinal study. This would enable analysis of whether or not digit sucking does act to alter treatment need. A cross-sectional investigation of non-referred patients may also be able to identify the impact of habits upon orthodontic treatment need more clearly than did the present study.

The present study has not addressed the issue of treatment for persistent habits, but clearly as habits represent a substantial amount of the new cases seen in the hospital orthodontic service, on-going audit of treatment of these children is remains very worthwhile, particularly during a period of increasing demand for orthodontic treatment.

## APPENDIX A

## STATISTICAL FORMULAE AND CONVENTIONS USED

1. Arithmetic mean. $$\bar{x} = \frac{\sum x}{n}$$

2. Standard deviation. $$SD = \sqrt{\frac{\sum(\bar{x}-x)^2}{n-1}}$$

3. Standard error of the mean. $$SEM = \frac{SD}{\sqrt{n}}$$

4. Method error. $$s = \sqrt{\frac{1}{2n}\sum(x_i-y_i)^2}$$

   Where $x_i$ and $y_i$ are pairs of repeat measurements for n=1 to i.

5. 95% confidence limit for method error. $$95\%\ \text{limit} = 1.96\sqrt{2\ s^2}$$

6. Two sample t test. $$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{SD^2}{n_1} + \frac{SD^2}{n_2}}}$$

7. Chi Square test. $$\text{Chi square} = \sum \frac{(O - E)^2}{E}$$

   Where O and E are the observed and expected values for each cell of the contingency table.

8. Yates correction for2x2 tables.

If the table is represented by:-

| | | |
|---|---|---|
| a | b | a+b |
| c | d | c+d |
| a+c | b+d | total |

Then,

$$\text{Chi square} = \frac{\{(|ad-bc|) - \frac{1}{2}(a+b+c+d)\}^2 (a+b+c+d)}{(a+b)(c+d)(b+d)(a+c)}$$

9. Kappa statistic for repeatability of categorical data.

If the table is represented by:-

| | | | |
|---|---|---|---|
| a | b | a+b | First Observation |
| c | d | c+d | |
| a+c | b+d | total | |
| Second Observation | | | |

Then,

$$P_e = \frac{(a+c)(a+b)}{total} + \frac{(b+d)(c+d)}{total}$$

$$P_o = \frac{\text{Number of perfect agreements}}{total}$$

And

$$K = \frac{P_o - P_e}{1 - P_e}$$

10. Pearson Correlation Coefficient.

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-x)^2 \quad (y-y)^2}}$$

11. Significance of Pearson correlation coefficient.

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

12. Mann Whitney 2 Sample Test.

(i) All cases placed in rank order by Variable B (for example hours of digit sucking per day)

(ii) Sum of ranks for each possible value of Variable A (for example sex) determined.

(iii) Smaller of the 2 totals is used.

(iv) $n_1$ = number of observations in that set.
$n_2$ = number of observations in the other set.

(v) Probability determined from Tables for the corresponding values of $n_1$, $n_2$ and rank Sum.

For this study, the Mann Whitney test was conducted by the Epiinfo statistical analysis computer program.

13. Kendall's Rank Correlation Coefficient for paired values. ($\tau$)

(i) Variables A and B are ranked.

(ii) The paired rankings are written out, with Variable A rank above Variable B rank, in rank order for variable A.

e.g.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable A Rank | 1 | 2 | 3 | 4 | 6 | 6 | 6 | 8 | 9...... |
| Variable B Rank | 8 | 14 | 5 | 7 | 1 | 10 | 3 | 11 | 5...... |

(iii) Starting with the first pair of ranks, and moving to the right, the number of Variable B ranks which are larger than the first reading are counted, and the number noted.

(iv) The process is then repeated for the second pair of ranks, and so on until all have been counted.

(v) When counting the number of ranks which are larger, ignore any cases which have tied values for the Rank of Variable A.

(vi) P = The sum of all these scores.

(vii) Repeat the count, but this time note the number of Variable B Ranks which are smaller.

(viii) Q = The sum of all these scores.

(ix) Let t = number of ranks in each of the groups of tied ranks in the upper row.

(x) Then,

$$T = \frac{1}{2}\sum t(t-1)$$

(xi) Let u = number of ranks in each of the groups of tied ranks in the lower row.

(xii) Then,

$$U = \frac{1}{2} \; u(u-1)$$

Finally,

$$\tau = \frac{P - Q}{\sqrt{\left\{\frac{1}{2} n (n-1) - T\right\}} \sqrt{\left\{\frac{1}{2} n (n-1) - U\right\}}}$$

14. Significance of Kendall's Rank Correlation Test.

$$\text{Standard Error of } (P-Q) = \frac{n(n-1)(2n+5)}{18}$$

# APPENDIX B

## EQUIPMENT, MATERIALS AND COMPUTER SOFTWARE USED

### A. Equipment.

1. IBM PS2 386 55SX personal computer.
   International Business Machines U.K. Ltd, Greenock, Scotland.
2. Numonics 2210-1212 digitiser.
   Numonics Corporation, 101 Commerce Drive, Montgomeryville, PA.18936. U.S.A
3. Hewlett Packard 7475A plotter.
   Hewlett Packard Company,18110 S.E. 34th Street Camas, WA 98607 U.S.A.
4. Hewlett Packard Deskjet 500 printer.
   Hewlett Packard Company, 18110 S.E. 34th Street, Camas, WA 98607 U.S.A
5. Siemens Orthoceph 10S cephalostat.
   Siemens PLC, Siemens House, Sunbury on Thames.
6. Fuji G8 radiographic film and cassettes.18cm x 24cm.
8. Radiograph viewing box.
   H.A. West, 41 Watson Crescent, Edinburgh, Scotland.
9. Orthodontic callipers with Vernier scale,
   Orthocare UK.

### B. Materials.

1. "Kromogel" Type 1, fast set, Class A germicidal alginate impression material.

Wright Healthcare Group Ltd, Kingsway West, Dundee, Scotland.

2. Dentaurum "O-Tray" orthodontic impression trays.
   Dentaurum, P.O.B. 440, D-7530 Pforzheim, Germany.

3. "Crystacal R Plaster".
   British Gypsum Industrial Products, U.K.

**C. Computer Software.**

1. "MS DOS" personal computer operating system, version 3.30
   Microsoft Corporation and International Business Machine Corporation.

2. "Dentofacialplanner Version 5.3"
   Dentofacial Software Incorporated,Toronto, Canada.

3. "Epi Info Version 5.0" Statistical analysis program.
   USD, Incorporated 2075 A West Park Place, Stone Mountain, GA 30087, USA.

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