THE EFFECTS OF SURGERY
ON FACIAL GROWTH IN
BILATERAL CLEFT LIP AND
PALATE SRI LANKAN
SUBJECTS.

by

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Abstract

A thesis presented on the effects of surgery and the timing of surgery on facial growth and morphology in the bilateral cleft lip and palate Sri Lankan subject. Mixed cross-sectional and longitudinal cephalometric data are used to compare the study cohort with a control Sri Lankan population.

The literature on bilateral cleft lip and palate is sparse. Papers solely on bilateral cases are few, with even fewer relating to longitudinal series in this group of patients. This retrospective mixed cross-sectional and longitudinal cephalometric study presents the results of 81 Sri Lankan BCLP subjects and studies the effect of surgery and the timing of that surgery on facial growth. The cohort comprises 58 males, age range 6 - 54 years and 23 females, age range 4 - 55 years. Lateral skull radiographs were taken between 1985 and 2002, each patient having a minimum of 2 and a maximum of 6 radiographs. This thesis examines a range in timing of surgical palatoplasty from infancy to adulthood. Cephalometric analysis explores both intrinsic and iatrogenic features in relation to the study hypotheses. The results support the hypotheses that the unoperated subject displays relatively normal facial growth. Lip repair demonstrated a moulding effect on the dento-alveolar component of the premaxilla but was not responsible for mid-face retrusion. Palatal surgery undertaken at anytime before or during puberty was found to cause deleterious effects to mid-facial growth. Conclusions drawn from this study show no benefit of delaying the hard palate repair from a facial growth perspective. It is suggested that it is the nature of surgical intervention and not the timing of that surgery that is the major factor affecting facial growth outcome.

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'Twenty years from now you will be more disappointed by the things you didn't do than by the ones you did do. So throw off the bowlines. Sail away from the safe harbour. Catch the trade winds in your sails. Explore. Dream. Discover.'   *Mark Twain*

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GLOSSARY

BCLA Bilateral cleft lip and alveolus.

BCLP Bilateral cleft lip and palate.

CL Cleft lip.

CLA Cleft lip and alveolus.

CP Cleft palate.

EW Emma Worrell.

ICP Isolated cleft palate.

LMS Age related growth centile program.

MM Michael Mars.

POSTLIP Post lip repair.

POSTPAL Post palate repair.

PSO Presurgical Orthopædics.

SD Standard Deviation.

SDS Standard Deviation Score.

UCLA Unilateral cleft lip and alveolus.

UCLP Unilateral cleft lip and palate.

UNOP Unoperated cleft lip and palate.

Chapter 1

INTRODUCTION AND HYPOTHESES TO BE TESTED

Studies into facial growth and morphology in the bilateral cleft lip and palate patient are few. In the western world surgery to repair the cleft of the lip is performed within the first months of life. Protocols for palatal surgery vary. Palatal repair before 1 year of age is conventional, although some centres delay palatal surgery until the age of 2. Some centres have introduced different surgical protocols with the closure of the soft palate in infancy but the hard palate repair may be delayed from 3 to 13 years of age.

The aetiology of cleft lip and palate is still unknown. It occurs in 1.31:1000 live births in the UK, (CRANE, 2003). The cleft population is varied in its presentation. Clefts can present as unilateral or bilateral lip and palate. Further, they may present with variable degrees of the cleft, for example complete clefts of the hard and soft palate or just small clefts of the soft palate only. Bilateral cleft lip and palate accounts for only 10% of the entire cleft population. Many clinicians regard bilateral cleft lip and palate patients as a serious surgical and orthodontic problem. These cases are difficult to treat, having soft tissue, skeletal, facial growth and speech problems. Patients often present with poor mid-face growth.

There has for some time been great controversy in the UK about which surgical factors have the most detrimental effect on facial growth or whether surgery itself causes the iatrogenic deformity. In the UK, cleft lip and palate surgery is generally complete in early infancy, and the experience of severe mid-face retrusion is common in the mature adult, (Mars et al., 1987; Mars, 1993). Maxillary retrusion, the underdevelopment of the middle third of the face is a common characteristic presented by a large number of patients with repaired palatal clefts in the Western world. Fig. 1.1 The cause of maxillary retrusion is still unknown although many controversies exist as to its aetiology. Facial growth disturbances in the cleft population have been investigated, studies have shown the retrusion to be mainly an iatrogenic deformity, (Mars and Houston, 1990; Mars et al., 1990; Mars, 1993).

Fig. 1.1 Maxillary Retrusion

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The Sri Lankan Project founded by Dr M Mars in 1984 has enabled more than 80 team members to date, to operate on over 700 patients. There have been 12 follow up visits to study cleft lip and palate on a longitudinal basis. This project has unique data on the unoperated and operated Sri Lankan cleft lip and palate population and 18 years longitudinal data on patients, as well as cross-sectional data and records on 497 healthy non-cleft Sri Lankan (control) subjects.

This study into the facial growth and morphology of the Sri Lankan bilateral cleft lip and palate subject is one of the largest research data sources available in the world. Sri Lankan bilateral cleft lip and palate subjects have not been investigated previously. This study has the world's largest longitudinal data collection of over 18 years on any bilateral cleft lip and palate series. In a unique way the method of analysing and presenting somatic growth measures has been modified to present healthy non-cleft facial growth parameters for the Sri Lankan population. The volume of data collected on the bilateral cleft lip and palate subject and the control population is unparalleled.

All the patients in this study are Sri Lankan; they attended Galle or Kandy for surgery or growth recordings on the data collection visits of 1984, 1985, 1986(twice), 1988, 1990(twice), 1995, 1998, 1999, 2000 or 2002. This is a study of 81 BCLP subjects. They had dental impressions, lateral skull x-rays, hearing and speech assessments, somatic growth investigations, photographs, psychosocial questionnaires and a complete medical and surgical history taken in each visit. In

all cases no pre-surgical orthopaedics or orthodontic treatment was undertaken. Cephalometric analysis of lateral skull radiographs will form the core of this study. Facial growth and morphology and the effects of surgery and the timing of that surgery on these subjects are to be investigated.

Hypotheses to be tested

In the BCLP subjects the following Hypotheses are proposed:

1. *The unoperated subject has the ability to achieve normal growth or an overgrowth of the Maxilla.*

2. *Lip Surgery has a moulding effect on the dentoalveolar component of the Premaxilla. This does not cause maxillary retrusion.*

3. *Surgery to the palate is potentially damaging to mid facial growth.*

4. *Early palatal surgery is more damaging to mid facial growth than later surgery.*

Outline of Thesis

The structure of each chapter of this thesis is now outlined.

Chapter 2 A review of the literature. An historical perspective reviewing the controversies associated with the nature and timing of surgery in relation to facial growth. Separate sections review the literature on unoperated subjects, operated subjects and the effects and timing of the lip and / or palate surgery.

Chapter 3 A) Subjects and Methods. Describes the methodology and includes a detailed description of the BCLP subjects in this study. The procedures used in this study are outlined. The facial growth parameters developed for the healthy non-cleft Sri Lankan population are described.

Chapter 3 B) Statistical Methods. Describes the Statistical methods used in this study.

Chapter 4 The Control Population. Describes the control population methods used in this study.

Chapter 5 Results. The Cephalometric analysis of facial growth and morphology. This chapter is subdivided into the Unoperated subject, the Post Lip repair subject, the Post Palate repair subject and the Facial growth outcomes beyond 18 years of age.

Chapter 6 Discussion of the results and Conclusions in relation to the hypotheses to be tested.

Chapter 7 Suggestions for further investigation.

Chapter 2

LITERATURE REVIEW

Bilateral cleft lip and palate is relatively rare and as such few studies are undertaken purely into this type of cleft and associated facial growth controversies. In a more recent report the incidence of cleft lip and palate in the UK was 1.31 in1000 live births, (CRANE, 2003). However, in this report the distribution of clefts did not differentiate between Bilateral and Unilateral cleft lip and palate. The percentage of clefts was reported as cleft lip only (21.4%), cleft lip and palate (30.1%) and cleft palate only (42.6%). The concerns regarding facial growth outcome, particularly the effect of surgery on mid-face growth and morphology are common to both BCLP and UCLP subjects. Therefore, this literature review considers both these groups.

BCLP remains a little researched field with considerable variation in treatment protocols, poor record collection, small sample sizes and pooled data (with other cleft types) leading to potentially erroneous conclusions. Many authors have tried to present larger data samples by mixing pre-pubertal and post-pubertal growth measurements, with males and females in the same groups and using controls

from different ethnic populations. These errors are potentially misleading, resulting in unsubstantiated conclusions regarding facial growth in BCLP patients.

The aim of this chapter is to survey the literature. The main areas of the reported literature will be discussed under the following sections:

1. Facial Morphology in the Unoperated Cleft Lip and Palate subject.

2. Controversy surrounding Facial Morphology of the Premaxilla.

3. Studies investigating the effects of Premaxillary surgery on Facial Growth.

4. Studies investigating the effects of Lip Repair on Facial Growth.

5. Studies investigating the effects of Palate Repair on Facial Growth.

6. Variations in Surgical Outcome

7. Facial Growth Parameters and Analyses in Cephalometrics

8. Control Population Studies

9. Effects of Pre Surgical Orthopaedics and Orthodontic Treatment

10. Normal Somatic Growth & Facial Growth

11. Catch up Growth

12. Malnutrition

1. Facial Morphology in Unoperated Cleft Lip and Palate subject.

Subjects with clefts who have reached adulthood without undergoing any form of treatment present a unique opportunity for the study of facial growth and morphology. The growth expressed in these subjects is the inherent growth potential of cleft subjects with no surgical or orthodontic intervention. Using this as the baseline of the 'natural cleft history' with no intervention it is then possible to determine the relative roles of intrinsic and/or iatrogenic factors that may cause the gross facial deformity often seen in later life.

A classical Mexican study was one of the first reports on the different facial morphology in the cleft subject, (Ortiz-Monasterio, 1959). He noted that early surgery produces under-developed maxillae. In his introduction he writes *'it is our impression that a greater percentage of growth defects are produced in early surgery than in later ones, even when treated by the most able hands.'* An early indication that it is not only the timing of surgery or the type of surgery performed but also the ability of the surgeon that may influence the subsequent facial growth. Cephalometric analysis studying the effect of palatal closure on a sample of 19 non-operated mixed cleft patients who had surgery after puberty is reported. The main emphasis of this study was cephalometric analysis, examining the angles to determine the forward development of the maxillary base. In his study he examined 18 unilateral and 1 bilateral cleft lip and palate subject, 12 male and 7 females with a mean age of 27 years, (age range 15 to 43 years). In the sample 15 out of the 19 were totally

unoperated, 2 had lip closure at age 6 and 8 years, 2 had lip and palate closure at 17 and 19 years and so were considered post-pubertal at the age of surgery. The title of this paper is "Cephalometric measurements on adult patients with non-operated cleft palate", however, he subsequently explains that 4 patients had previous operations. Comparison was made between this group and the previously published normal growth samples of Downs and Mayne. He found that surgery after palatal growth has ceased does not affect maxillary growth. All had normal or greater than normal maxillary growth. The increased maxillary protrusion can be attributed to lack of containment by the normal continuity of the lip. In this paper there does not seem to be any distinction made between the UCLPs and the one BCLP subject. Males and females are pooled, the resulting comparison with the Downs and Mayne studies, which are from a different racial background compromise the conclusions. In summary this paper found the non-operated adults showed the forward growth of the maxillae to be the same or greater than in non-cleft cases. He concluded that a greater percentage of good results can be obtained if palate surgery is postponed until the patient's facial growth is very well advanced and recommended a delay of palatal surgery until 5 years of age, '*an age that is still compatible with a good speech therapy program*'. No evidence to support such recommendations was provided.

In a later Mexican study of untreated adult cleft palate patients 63 patients were examined, again these patients are reported as unoperated but some have had lip

repair at an early age, (Ortiz-Monasterio et al., 1966). The sample consisted of 42 UCLP and 14 BCLP, 24 males, 29 females with an age range 14 to 52 years, the mean age 28. In this study there were 7 incomplete clefts included. Physical examination of the patients noted no absence of soft tissue in the unilateral cleft subjects only a mal-position of structures. The width of the palatal cleft was much wider in the adult cohort as compared to a child cleft sample. Smaller palatal clefts were seen in patients who had lip closure at an earlier age, the lip repair producing narrowing of the maxillary segments. The resulting surgical problem of the adult cleft is attributed to the palatal displacement of the maxillary segments into the nasal cavity. There were associated problems with the underdevelopment of the soft palate muscles reported. In the BCLP group severe underdevelopment of the columella and prolabium was observed. The deficiency of the columella and prolabium appears greater when compared with patients who had early lip repair, emphasizing the stretching effect and muscular action on the growth of the prolabium. Ten cases showed that the lengthening of the columella at the expense of the prolabium produced a tight upper lip requiring secondary correction. The premaxilla was prominent and unstable in 14 of the 17 bilateral cleft subjects, with the remaining 3 having incomplete BCLP. A prominent premaxillary position was also noted in the adults with unilateral cleft lip and palate when compared with a normal population. Concluding comments in this

paper were that the untreated adult UCLP and BCLP subjects exhibited normal growth of the middle third of the face.

The paper reports on unoperated adults, all patients had an unoperated cleft palate yet some had had early lip repair. The cohort also includes 14 year olds as mature adults. The authors' attribute some growth disturbances due to the pressure exerted by the lip repair but only conclude that normal facial growth of the middle third of the face is confirmed in this series, (Ortiz-Monasterio et al., 1966). An interesting observation in this study was that the Mexican adult cleft patients were primarily concerned with their external facial deformity. Sixty percent of cases that had their cleft lip closed never attended for their palate repair. However, *closing the palate first gave satisfactory results and if the lip is left open the patient will return and we are able to observe our results*.

Retrospective studies to compare the craniofacial morphology of adult unoperated complete BCLP subjects with a non-cleft group are reported from the University of Sao Paulo, (Filho et al., 1998). This study of 28 subjects, 20 males and 8 females, ranging from 15 to 41 years, was performed on lateral cephalograms. Cephalometric analysis included both skeletal and soft tissue points. The control groups were matched for gender and age. Within this study males and females who have not reached their full growth potential have been incorporated in the reported age range. This tendency to bolster the sample sizes leads to misguided conclusions into craniofacial morphology and facial growth

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outcomes as some of the samples have yet to reach their full growth potential. The authors found that the most significant difference between the groups was the prominent premaxilla in the cleft group giving a convex facial profile. Cephalometric analysis showed a long lower face height and a reduced posterior face height, with no difference in cranial base angulation in the bilateral cleft group. In comparison to the non-cleft group the cranial base dimensions were smaller. He concludes that *'the initial characteristics of the cleft malformation persist during growth'*.

In a Reflex-microscope study, the maxillary arch form of 41 Sri Lankan adults with unoperated unilateral cleft lip and palate were compared to a control group of 100 non-cleft Sri Lankan adults,(McCance et al., 1990). Teeth in the unoperated cleft group were smaller than in the control group. Arch widths in the cleft groups were reduced more anteriorly than posteriorly than in the control group, resulting in more V-shaped arches and greater overjets in the cleft groups.

In summary these papers describe the natural cleft history of the unoperated cleft patient having normal or greater maxillary growth, underdevelopment of the columella and prolabium, prominent and unstable premaxillae leading to a convex facial profile. Cephalometric analysis showed a long lower face height, reduced posterior facial height, and no difference in cranial base angulation only smaller in linear dimensions when compared with their non-cleft counterparts. Teeth in the

cleft group were smaller and arch widths more reduced anteriorly resulting in V-shaped arches and greater overjets.

These reports highlight the differing facial morphology and varying presentations of the unoperated cleft lip and palate subject, (Mars and Houston, 1990; Mars, 1993).

2. Controversy surrounding Facial Morphology of the Premaxilla.

It is generally accepted that facial growth especially mid-face growth is abnormal in many cleft lip and palate subjects; however, the aetiology of these differences is of great debate. Some authors declaring an intrinsic cleft growth deformity while others believe it is an iatrogenic deformity.

Ross reports on the rapid changes that occur in facial morphology following lip repair. In bilateral cases the surgical reconstruction of the lip leaves the nose symmetrical, wide and flat due to the distorted alar bases and short columella, (Ross and Johnston, 1978). The restored lip is stretched over a protruded premaxilla, this tension slowly moulding the premaxilla downwards and backwards. However, premaxillary protrusion remains throughout childhood. These findings are supported by others authors,(Semb, 1991; Trotman and Ross, 1993). A short upper lip in the operated subject may tend to permit the

continued protrusion of the premaxilla, with the lower lip falling behind the upper teeth, exaggerating the protrusion; resulting in a gross facial deformity.

In the first paper in a large series, 1600 cephalometric radiographs of 538 males (from 15 centres) with unilateral cleft lip and palate were examined to determine the effects of treatment on growth. Ross describes the abnormal facial morphology as consisting of intrinsic, functional and iatrogenic growth distortions. Intrinsic abnormality of the maxillary complex, functional growth factors affecting facial symmetry and iatrogenic factors implicating surgery as the major source of mid-face deficiency in cleft lip and palate patients, (Ross, 1987b). In the introduction to his study he reports '*it is probably true that all surgical treatment for unilateral cleft lip and palate inhibits or distorts facial growth to some extent.*'

A histological study of 7 BCLP aborted human foetuses and post-natal specimens reported the premaxilla to be severely protrusive at 10 weeks pre-natal, becoming more protruded at 6 weeks post-natally, (Latham, 1973). At full term the premaxilla's protruding malformation was ' *noted to be by the horizontal alignment of the alveolar bone. In contrast to the control sample which was in the vertical plane*'. The author found in the control sample that the premaxilla moved down in a vertical plane. However, in the BCLP subjects the premaxilla remained high and grew out in a horizontal plane, producing the severely protrusive premaxillary segment. The premaxilla in the BCLP subjects began to protrude at 35 days prenataly and kept protruding postnataly. The author noted 3 factors contributing to the

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protuberance were the septo-premaxillary ligament, abnormal direction of alveolar bone growth and the possible underdevelopment of maxillary segments. In a later study, Latham reported on the structure and anatomy of the columella, his conclusions highlighted the prominence of the protruding premaxilla which was in agreement with his earlier findings, (King et al., 1979).

Issues regarding the size and shape of the premaxilla are reported. The size and shape is dependent on the number of tooth buds and their distribution according to Berkowitz. In this study no numbers of subjects were stated just anecdotal evidence. He further states that the cause of premaxillary protrusion is the tension and resulting overgrowth at the premaxillary-vomerine suture,(Berkowitz, 1996). Displacement of the premaxillary-vomerine suture by the muscular force of the tongue pushes the premaxilla forward. Cephalometric data showed that the premaxilla was postured forward on the facial profile at birth with marked palatal hypoplasia in bilateral cleft lip and palate patients. Other papers support these findings, (Coup and Subtelny, 1960; Ross and Johnston, 1978).

Overgrowth of the premaxilla is attributed to the lack of restraint on the premaxilla by the lip, (Berkowitz, 1996). The intact obicularis oris muscle would restrain the overgrowth of the premaxillary-vomerine suture.

Boo-Chai notes that the size of the prolabium differs due to the lack of blood supply and musculature, (Boo-Chai, 1971). The study looked at patients over 15 years and noted that of the 9 males, 1 had sparse hair and 8 had no hair on the

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prolabium. The author suggested that the small prolabium and lack of hair was due to a restricted blood supply. This study was unconvincing and provided no real evidence.

A study examining adult craniofacial morphology found the most significant difference to be the prominent premaxilla in comparison to a non-cleft sample. Even as an adult the premaxilla was protrusive, (Filho et al., 1998).

Dahl's classic study of the morphology in congenital clefts of the lip and palate has been well regarded as baseline data for over 30 years, (Dahl, 1970). The investigation studied 104 UCLP male subjects with an age range of 18 – 33 years, 24 had had lip repair only and 78 had lip and palate repair. In this study the 'morphology' between the Control and Cleft population is investigated. Dahl found that the cranial base lengths were smaller and upper face height was reduced both anteriorly and posteriorly. The length of the maxilla was shorter but also the mandible is not only smaller but retrognathic in contrast to the non-cleft group.

In another paper the comparison was made between an unoperated and operated cleft group with 32 control subjects to evaluate the anterior-posterior craniofacial relationships, (Bishara, 1973). In this study 20 female ICP subjects at 18 years (age range 15.9 – 21.5) were divided into two study groups, 12 had palatal surgery and 8 had their open palatal cleft obturated. The 'total cleft group' examined in this study combined both the subjects who had had palatal surgery and those that

had their open palatal cleft obturated. The maxilla was in a more posterior position in relation to the cranial base in the 'total cleft group'. The mandibular positions were relatively posterior in relation to the cranial base. The relationship of the maxilla and mandible (ANB) to the cranial base showed no significant differences between the cleft and control group. Analysis between the palatal surgery and obturated group showed no significant angular or linear measurement differences. The author concluded that such differences are not necessarily due to the palate surgery but may be the intrinsic cleft palate growth tendency. *When cleft palate only individuals are compared to normal individuals the latter should be used mainly as reference or base line rather than to detect differences since the cleft and normal samples are essentially representatives of two populations with different craniofacial characteristics.*'

The previous group of papers all support the theory that inherent or intrinsic cleft deformities exist, not necessarily caused by any surgical intervention.

The following literature investigates the surgical effect on the premaxillary segment, if any, on facial growth.

3. Studies investigating the effects of Premaxillary surgery on Facial Growth.

The fundamental difference between the BCLP subject and the rest of the cleft population is the premaxilla. There is great debate in the literature as to the effect of premaxillary surgery on facial growth. Many have reported on its protrusive nature and many have attempted surgical repositioning of the premaxilla with varied degrees of success.

3.1 Studies supporting Normal Growth of the Premaxilla

Studies have investigated the relative position of the premaxilla. Frontal and lateral cephalometric analysis of a mixed longitudinal sample over a 40-year period is reported, (Semb, 1991). In this study 90 BCLP subjects, 61 males, 29 females were analysed from the Oslo archive, to study facial growth. The advent of new surgical techniques, alveolar bone grafting in 1977 and the standardizing of surgery protocols are noted in this paper. Lateral and frontal cephalograms were obtained 1 year apart and digitised under standardized conditions. Skeletal and soft tissue landmarks were analysed. It was noted that although the premaxilla was prominent at first it receded during the facial growth period until it became normal in comparison with the non-cleft population. Differences between the sexes were tested by repeated analysis of variance. The only

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statistically significant difference for angular variables was that the cranial base is more obtuse in girls and showed greater increase over time. Repeated analysis of variance did not show differences attributable to the presence of Simonart's bands.

In a report on operated cases severe protrusion of the premaxilla was recorded, (Trotman and Ross, 1993). In a longitudinal study of 30 male BCLP subjects lateral skull radiographs were examined, at 6-years, 12-years and as an adult. Cephalometric measurements and Tensor Biometrics were used. Tensor Biometrics is a geometrical process of evaluating spatial change. The cephalograms were superimposed on the Nasion - Basion line. The author found the premaxilla to be severely protrusive at 6 years but in a normal position as future growth occurs. Pre-surgical orthopaedics and orthodontic treatment was used on all but 6 cases.

In summary authors have found the premaxilla to be protrusive at birth but with further growth the premaxilla adopts a more normal relationship within the dental arch form. Discrepancies occur in the literature as to the age at which this normal relationship is obtained. However other authors have noted contrasting observations with regard to the positioning of the premaxilla.

3.2 Studies supporting Abnormal Growth of the Premaxilla

An early paper examines the surgical recession of the premaxilla and its effect on maxillary growth in the bilateral subject, (Monroe et al., 1970). The study starts with 50 BCLP subjects but only examines 20 patients who underwent surgical setback of the premaxilla. Each patient had a different surgical protocol. One patient had complete surgical resection of the prominent premaxilla. The effect on maxillary growth of 20 cases was judged on appearance, occlusion and cephalometric films. The author showed that at age 9 marked retrognathia and a flat facial appearance could be seen. Most cases had a good occlusion but the premaxilla was in deep overbite. This study examined subjects between the age of 8 and 15 years, half were only 9 years old, too young to draw such conclusions. However the author noted that the position deteriorated with further growth. A further finding reported was that *'if recession of the premaxilla is done with care and due regard for the growth areas it may be done without making the patient a dental or cosmetic cripple'.*

In a study of 95 unoperated BCLP cases, the effect of the premaxilla in relation to the maxillary arch form was investigated, (Boo-Chai, 1971). This study incorporated 27 BCLP subjects, 12 non-operated subjects, 10 bilateral lip only and 5 who underwent lip and premaxilla surgery. In the lip repair group only one subject had a marked protrusion, the premaxillae were moulded back into the

maxillary arch form. In another group, 5 subjects whose the premaxillae were trapped anteriorly, had the premaxilla surgically removed. Within this group 4 out of 5 had severe maxillary retrognatism. The author notes *'Removal of the premaxilla – the maxillary cornerstone had a disastrous effect causing maldevelopment of the middle third of the face in later life.'* This article is heterogeneous and of limited value for analysis, comprising many different sub groups.

Some authors support surgical repositioning of the premaxilla prior to lip surgery with varying effects on facial growth, (Monroe et al., 1970).

The long-term effect of premaxillary setback on facial skeletal profile in BCLP subjects has also been reported, (Friede and Pruzansky, 1985). Two groups of patients were analysed, 6 had early premaxillary setback at 4 months, and 67 had late setback at 5 years. The cephalometric analysis was performed at a mean age of 17 years. The early setback group contained a mixed severity of protrusion but the late setback group was pre-selected because of the severe mid-face protrusion. The author notes that, *'for good end results the premaxilla should not be set back into a 'complete fit' with the maxillary arch as the mid-face then risks being outgrown by the mandible'.* No statistical differences were found between the two groups examined in adolescence, with the average result becoming a concave skeletal profile. The author noting that *'the extreme facial convexity of infants with BCLP decreases considerably with age as a result of treatment and age.'* The same effect of premaxillary surgery can be seen if undertaken in pre puberty. However the general effect of palate surgery

as an important variable is ignored. Bias was introduced in this study due to the pre-selection of severe cases.

The growth of the Premaxilla in the BCLP subject was investigated in 63 male BCLP patients, (Vargervik, 1983). Two groups comprised 51 subjects who had no surgical setback of the premaxilla and 12 subjects who had early setback surgery. The author stated that at birth the premaxilla is sent forward on the mid-face structures of the nose. In the 51 patients without elective premaxillary setback, the premaxilla was protruded until 12, then gradually retruded. All 12 patients who had early setback showed less pronounced premaxillae during growth and only achieved half the normal growth rate. All patients had presurgical orthopaedics, orthodontic treatment, extra oral traction and Quad helix appliances during their growth periods. The author notes *'Prominence of premaxillae is desirable in the primary and transitional stages. Premaxillary protrusion gradually disappears in the non-operated group. Surgical procedures that reduce prominence and forward growth result in severe mid-face underdevelopment, which then requires surgical management of the Maxilla or the entire mid-face.'*

Friede concluded in his study that traumatic surgery involving the premaxillary-vomerine suture would be likely to contribute to impaired mid-facial growth, (Friede, 1973).

One paper examined facial growth in a 33-year longitudinal follow up, of a single 15-year-old BCLP patient who had his premaxilla surgically removed, (Rees,

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1991). This patient presented with an unoperated bilateral cleft lip and palate with a protruded premaxilla, which was trapped anteriorly out of the maxillary arch. Other characteristics displayed were a hypoplastic prolabium, no hair on the prolabium, shortened columella and unintelligible speech. The same characteristics were also noted by other authors, (Boo-Chai, 1971). Dental models, cephalograms and dental x-rays were taken throughout the follow-up period. The premaxilla was sacrificed at the lip repair operation. The maxillary segments were in good relation to the mandible with no retrusion and a good facial profile.

The surgical removal of the premaxillary segment is now a rare treatment choice but the lessons learnt from experiences of premaxillary osteotomies are invaluable. Premaxillary setback procedures are still used today but the deleterious effect on facial growth is widely reported.

4. Studies investigating the effects of Lip Repair on Facial Growth.

4.1 Effects of Lip Surgery on the Premaxilla – Animal Studies

Two articles by the same author claim that lip surgery is responsible for mid-face growth inhibition, (Bardach et al., 1979; Bardach, 1990). The evidence is based on animal experiments performed on rabbits and beagle dogs. 'Clefts' were

surgically created by the removal of 5mm wedges of lip, alveolar process and a section of the palate. The animals were grouped into three different groups; lip closure only group, lip and palate closure group and a no repair group. Experiments such as these can provide information on wound healing but the credibility of the results are in doubt when direct comparison between the surgically made 'cleft' and the congenitally occurring defect in cleft lip and palate subjects. The surgical trauma of tissue excision is likely to be more damaging to the surrounding tissue than any surgery to repair the existing congenital deformity.

4.2 Effects of Lip Surgery on the Premaxilla – Human Studies

Some authors agree that the repair of the cleft lip is primarily a cosmetic procedure but the lip repair can cause mild inhibitory influence on the long-term growth of the maxilla, (Ross, 1987c; Mars and Houston, 1990; Mars, 1993).

4.3 Studies supporting Normal Growth after lip repair.

Longitudinal studies into the effect of late primary lip repair upon the dento-alveolar morphology of UCLP Sri Lankan subjects have been published, (Muthusamy, 1998). The reflex microscope was used to digitise landmarks on dental models and a microcomputer analysed the sagittal, vertical and transverse

changes. Four main areas were investigated; dento-alveolar retraction, arch shape, dento-alveolar change vs. skeletal change and maxillo-mandibular relationships. This study comprised 26 unoperated UCLP Sri Lankan subjects, 19 males and 7 females. Preoperative, post lip surgery and post palate repair dental study models were measured. The subjects were divided into young and mature groups. His results found that lip repair exerts its effect at the dento-alveolar level. Lip repair had a dentoalveolar moulding effect on the upper labial segment in UCLP subjects. Lip repair approximates the widely separated cleft segments; this facilitates the repair of the alveolus. This is in agreement with other Sri Lankan findings in the lip surgery group in Mars' PhD dissertation, (Mars, 1993). The author concluding that lip repair had an orthodontic moulding effect on the dental alveolus, but not to the detriment of facial growth. Other authors have also reported these findings, (Mars and Houston, 1990; Arshad, 1998).

In another paper it was noted that prior to palate repair posterior arch widths had increased and anterior arch widths decreased due to the reconstructed lip, (Honda et al., 1995). However, this was not thought to be a facial growth inhibitor only dento-alveolar moulding phenomena.

4.4 Studies supporting Abnormal Growth after lip repair

Many papers demonstrate abnormal growth patterns after lip repair. Maxillary contraction is mostly due to the extra-oral pressure of the muscles of the face acting on a divided maxilla. According to a report on the early management of bilateral cleft lip and palate, (Glass, 1970). Distribution of the cleft types from 1000 cases attending East Grinstead showed 18% of the clefts were bilateral. The author notes that *'the important feature of this cleft type is that it divides the maxilla into three separate segments, two lateral maxillary segments and one premaxillary segments, providing many problems for those responsible for their solution'.* This article does not include the age ranges of the 180 patients. The paper outlines the treatment protocol at this one centre and the timing of the presurgical orthopaedic and orthodontic appliances used. The author concludes that lip repair exerts pressure on the maxillary segments causing arch collapse long before any palatal surgery. However this paper is anecdotal without objective evidence to support its conclusions.

In a study of 93 Brazilian male adults the isolated influences of lip and palate surgery was compared between operated and unoperated males with UCLP, (Filho et al., 1996). The sample contained 35 totally unoperated, 23 who had had lip surgery only and 35 lip and palate repair, the age range of the male subjects was from 15 to 42 years. The author found that there were no statistical

differences in the soft tissues between the lip only and the lip & palate operated groups, although changes were noted due to the deteriorating dento-skeletal profile. In comparison with the non-operated group, only the lip surgery group showed to have dento-alveolar and basal retrusion. Changes were seen in the overjet and the author noted this was due to the lip surgery because there was no significant difference between the lip only and the lip & palate group. The author included 15 year olds as mature adults and the mean age for the operated lip and palate group was 18 years, which could be pre pubertal in the Brazilian population. In this study no statistical differences where seen on the cephalometric analysis. They concluded that lip surgery is the most important factor in maxillary growth disturbance. Premaxillary retrusion is a dento-alveolar phenomenon and not the same as basal maxillary retrusion. This was in agreement with other authors, (Mars, 1993; Ross, 1970).

In a consecutive series of 57 patients with UCLP the speech, dental condition, skeletal and soft tissue facial growth was evaluated, (Enemark et al., 1990). The sample of 57 subjects, 42 males and 15 females were studied from birth to 21 years of age in a longitudinal study. All patients had the same surgery protocol of lip and hard palate closure with a vomer flap at 10 weeks old. Palatoplasty was performed at 22 months. Lateral cephalograms were taken at age 5, 8, 12, 16 and 21. None of the UCLP subjects exhibited a normal growth pattern. The skeletal and soft tissue facial growth was influenced by both the congenital anomaly and

its surgical treatment. The authors concluded that many factors influence the growth pattern, including surgery, surgeon and type of operation. No concluding comments suggested which factors hindered the facial growth and speech. The authors of this longitudinal study concluded that none of the patients had a normal speech structure or a normal facial growth pattern.

Ross (1987) in an extensive multi centre study analysed cephalometric radiographs contributed by 15 centres around the world. In the first paper in a large series, a sample of 1600 cephalometric radiographs of 538 males with unilateral cleft lip and palate were examined to determine the treatment affecting growth, (Ross, 1987b). Ross describes the abnormal facial morphology as consisting of intrinsic, functional and iatrogenic growth distortions: Intrinsic abnormality of the maxillary complex; Functional growth factors affecting facial symmetry; Iatrogenic factors implicating surgery as the major source of mid-face deficiency in cleft lip and palate patients. In the introduction to his study he reports *it is probably true that all surgical treatment for unilateral cleft lip and palate inhibits or distorts facial growth to some extent.* This study of 463 (of the 538) male subjects between the age of 10 and 33 had a mean age of 16.1 years. Normal non-cleft individuals were used as the 30 control subjects with a mean age of 16 years. Radiographs were taken on all the unilateral subjects and controls, which were traced on to acetate paper and fed into the computer to be digitised direct on screen. A series of plots with angular, linear measurements were calculated from

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the data input. Plots were computer generated and enabled the inter-relationship of landmarks to be assessed. Cephalometric analysis was presented in groups of good, medium and poor facial growth. No statistical analysis was included, however he concluded that basic differences in facial growth existed between the study males and the control males. The differences were confined to the maxillary complex and the mandibular posture. Differences between the cleft males, who received different treatment, lead to treatment-induced morphological differences.

The next paper in this series reports on the repair of the cleft lip. Ross examined the age at the lip repair of 413 male subjects. The cohort were divided into three groups; 55 cases had repair under 3 months of age, 108 cases at 3 months and 115 cases who had lip repair at 4 months or older, (Ross, 1987c). The study aim was to determine whether variations in timing and techniques have different effects on facial growth. All subjects had had palatal repair but in this paper only the effect of the timing of lip repair was examined. Radiographs were examined at 14 years of age. The variations encountered in the timing and technique of cleft lip repair had an insignificant impact on facial growth or dentoalveolar development. Nine different types of lip repair techniques were used. Some subjects having had repair of the alveolus and alveolar bone grafts in early infancy. With so many variations in the protocols for surgery it is hardly

surprising that no significant effect on the timing and technique on facial growth could be seen.

5. Studies investigating the effect of Palate Repair on Facial Growth.

Maxillary retrusion is evident in a proportion of operated cleft lip and palate subjects in their teenage years, (Ross, 1970; Ross, 1987a). Retrusion does not happen in all cases but the need for maxillary advancement has been reported as being around 25% (Ross, 1987a) or even as high as 50%, (Mars et al., 1987). Cross centre studies show significant differences between centres, (Shaw et al., 2001a).

The timing and technique of palatal closure in the cleft lip and/or palate subject is widely reported in the literature. Some authors believe surgery has no role in the mid-face retrusion often seen in cleft subjects in later life, believing intrinsic cleft growth phenomena are responsible. Others believe early palatal surgery causes the iatrogenic growth deformity; while some believe a later more delayed hard palate closure is more favourable for facial growth. Yet others claim that children with UCLP grow much like children without clefts, (Aduss, 1971). Some authorities even claim that surgery actually encourages rather than inhibits facial growth, (Krogman et al., 1975). Most authorities agree that facial growth in cleft

lip and palate subjects is not normal, (Enemark et al., 1990; Semb, 1991; Semb and Shaw, 1998).

One view is that there is no effect of surgery on facial growth. Craniofacial growth was analysed in a longitudinal growth study from 4 to 14 years of age, (Aduss, 1971). The study was of 71 patients with UCLP, 50 males and 21 females. Comparisons were made between the cleft cohort and a non-cleft group. The results showed that the craniofacial growth and development of the cleft sample was the same as the non-cleft population. The principal differences between the two population groups were the gonial angle, which was considerably larger in the cleft group and the anterior cranial fossa, which was elevated in the cleft group. Results from this study, according to the author, negate the conclusions that surgery causes deleterious effects on mid-face growth. However this study only followed the patients until the age of 14 when only some of the facial growth has occurred but with subsequent craniofacial growth studies on the same subjects the author may have come to a different conclusion.

5.1   Early Palate Repair

Early palatal repair is usually considered to be between six months and 2 years. However many centres vary in the timing and techniques of the repair. In some

papers early closure of the palate is regarded as any age less than 5 years of age, (Hotz et al., 1978; Hotz, 1969).

The argument is made of no significant effect on growth after palatal surgery in the isolated cleft palate patient, (Bishara, 1973). In this study 20 female ICP patients at 18 years, (age range 15.9 – 21.5) were compared with 32 control subjects to evaluate the anterior-posterior craniofacial relationships. There were two study groups, 12 had palatal surgery and 8 had their open palatal cleft obturated. The maxilla's relationship to the cranial base in the total cleft group, which comprised both the obturated and palatal surgery groups were analysed with the control group. A more posterior position in relation to the cranial base was found in the total cleft group. Results based on a combined total cleft group comprising open palatal clefts which are obturated and subjects having had palatal closure are of little value. However, the author found that mandibular positions were relatively posterior in relation to the cranial base. The relationship of the maxilla and mandible (ANB) to the cranial base showed no significant differences between the cleft and control group. Analysis between the palatal surgery and obturated group showed no significant angular or linear differences. Bishara concluded that such differences are not necessarily due to the palate surgery but may be the intrinsic cleft palate growth tendency.

Certainly that all palatal surgery is not detrimental to the growth process is the view of one author, (Berkowitz, 1996). All surgery need not to be delayed

pending completion of a major portion of maxillary growth is his opinion. Results from his treatment showed that surgery can aid and direct natural developmental processes through the re-establishment of more normal muscle forces. He goes on to report that the *ultimate fate of the facial profile is not always under the surgeon's control and the skeletal growth and development can be damaged by doing too much surgery too soon or doing it unskilfully*. Berkowitz concluded that in BCLP post-pubertal facial and palatal growth patterns are the eventual determinants of the treatment outcome.

In a longitudinal study of 95 Japanese children the maxillary arch dimensions were examined, (Honda et al., 1995). The sample comprised 7 CLA only subjects, 52 UCLP, 24 BCLP and 12 ICP subjects. Dental models were analysed pre-lip repair (4 months old), pre-palate repair (age 2) and at 4 years old. The UCLP and BCLP groups both presented with wider posterior arch widths with the BCLP patients having larger anterior arch widths prior to lip repair. Prior to palate repair the posterior arch widths had increased and the anterior arch width decreased, due to the moulding of the arch by the pressure of the reconstructed lip. The 24 BCLP subjects all had elastic strapping to align the pre-maxilla prior to lip repair and subsequent palate repair at 2 years of age. At 4 years of age the study showed that the UCLP and BCLP groups had smaller anterior arch widths and displacement of the maxillary segments palatally. The premaxilla in the BCLP group was set back by the moulding action of the strapping, prior to lip repair

and the reconstructed lip. The author concludes that '*palatoplasty had a negative effect on the growth of the maxillary arch in both transverse and antero-posterior dimensions*'. No follow-up of the 95 Japanese children after the age of 4 years is reported to either substantiate or negate these findings.

The timing of hard palate closure and dental arch relationships in UCLP is reported, (Noverraz et al., 1993). This mixed longitudinal study examined 88 consecutive UCLP subjects treated at the Nijmegen cleft centre. The cohort was divided into 4 groups, dependent on the age at which palatal surgery was performed. Two surgeons performed the same operations leaving the timing of palatal repair as the only variation in treatment protocol. In Nijmegen the normal surgery protocol was lip repair at 6/12, soft palate repair at 1 year. The hard palate repair group was subdivided into groups at 1.5 years, 4.6 years, 9.4 years and one group who had no palatal surgery. Dental arch relationships were evaluated using the GOSLON Yardstick. The GOSLON yardstick is a clinical tool that allows categorisation of unilateral cleft lip and palate dental arch relationships in the late, mixed, or early permanent dentition, (Mars et al., 1987; Mars et al., 1992). The yardstick grades dental arch relationships from excellent to very poor in 5 groups. Grade 1 presents with overjets and no maxillary retrusion, Grade 5 presents with severe reverse overjets and severe maxillary retrusion. The GOSLON yardstick is now an accepted measuring tool to assess arch form and facial growth in the unilateral cleft lip and palate,(Mars and Houston, 1990;

Hathorn et al., 1996). The dental arch relationships were examined at the four stages of dental development; deciduous dentition, early mixed dentition, late mixed dentition and the permanent dentition. The authors found no significant differences between the timing of hard palate closure and dental arch relationships. However some patients required pharyngeal flaps because of velopharyngeal insufficiency. In this group some minor unfavourable effects on dental arch relationships were noted.

A preliminary study of cephalometric and GOSLON outcome of facial growth and morphology in the unoperated male UCLP Sri Lankan subject over 13 years of age was undertaken, (Mars and Houston, 1990). Dental study models and lateral skull radiographs were analysed. The results showed that subjects who had no surgery had the potential for normal growth. Subjects who had lip repair early in infancy showed relatively normal maxillary growth. However, maxillary retrusion was common when the palate was repaired early. In a parallel Sri Lankan study on the effect of late primary lip repair on the UCLP subject it was noted that lip surgery although moulding the arch form does not have a detrimental effect on facial growth, (Muthusamy, 1998). The reports agree that early palatal surgery, not lip surgery results in the severe mid-face retrusion, which is widely experienced in the UK, (Arshad, 1998).

In his PhD, Mars examined the effects of surgery on facial growth and morphology in Sri Lankan UCLP subjects, (Mars, 1993). The database on the

facial growth and morphology of Sri Lankan cleft lip and palate subjects is one of the largest research databases on cleft lip and palate subjects in the world. Mars examined 130 UCLP subjects; the study was divided into 3 main groups. Firstly the unoperated group, then the post lip repair group and lastly the post lip and palate repair group. All groups were compared with a control population of 57 males and 52 females. For this cohort the lip and/or palate repair was performed in infancy by Sri Lankan surgeons. Each group was subdivided into a young and mature group. The main conclusions found were that early palatal surgery in infancy is associated with severe maxillary retrusion and subsequent deficiency of maxillary growth in both antero-posterior and vertical dimensions. These effects are more evident during the accelerated pubertal facial growth period. Subjects with open palates showed good growth of the maxilla. Subjects who had early palate repair showed little mid-face growth during puberty, exhibiting stunted maxillary growth. Lip surgery was found to have no effect on facial growth only dentoalveolar moulding. These are findings supported by other authors, (Muthusamy, 1998; Arshad, 1998). In his unoperated group excessive protrusion of the maxilla in relation to the cranial base was seen. However the length of the maxilla was the same as the non-cleft controls. He concluded that the protrusion of the maxilla is an expression of the unrestrained forward movement in space when the lip is left unrepaired.

Other authors have clearly demonstrated relatively normal maxillary protrusion in young UCLP subjects that deteriorate with age, (Enemark et al., 1990; Semb and Shaw, 1991).

Mars found that male subjects demonstrated smaller but significant intrinsic growth deficiency in facial depth, upper and total posterior face height. The mandible is both retro positioned and smaller in the operated UCLP subject but the mandible is not retro positioned in the unoperated group. These would support the hypothesis that this is a result of surgery too close to the palatal growth centres with incisions near the insertion of the medial pterygoid muscle on the pterygoid plate. Other authors support these findings, (Ross, 1987d; Ross, 1987e). The major effect of surgery seems to be in a reduction of ramus length. In his PhD (Mars, 1993) he concludes *'Palatal surgery severely compromises facial growth. Facial growth may also be compromised (though not to the same extent) in the totally unoperated subject because of cultural and psychological factors'.* The effect of cultural and psychological factors on growth is discussed in more detail later in the literature review.

5.2   Delayed Hard Palate Repair

The debate concerning the possible deleterious effects of surgery, the timing of palatal repair and the suggestion of delayed hard palate repair was first reported over 80 years ago, (Gillies and Fry, 1921). This is the earliest account suggesting

the potential deleterious effects of palatal closure in cleft palate subjects. They conclude: *All unoperated hard palate cases have normal occlusion of the non-involved teeth. Nearly all operated hard palates have abnormal occlusion of the non-involved teeth. In cases of malocclusion of the teeth in an operated palate such a serious defect may definitely be assigned to the result of the operation and would not have occurred had the hard palate been left alone.* The authors advocate closure of the soft palate and delayed closure of the hard palate with a prosthetic obturator until palate repair. The landmark paper by Gillies and Fry, like so many of the period, is based on anecdotal evidence. No indication of the number of patients or any subsequent patient follow up is reported.

Two main types of delayed palatal closure techniques are reported in the literature. Firstly, the conventional hard palate repair technique. Secondly, the lip and soft palate closure at three months of age with the remaining hard palate repair at around the age of 5 or even as late as 12 years. In 1944 Schweckendiek began early closure of the soft palate while leaving the hard palate open to allow the development of the maxilla. The patient was fitted with an obturator until the hard palate closure at the age of 12 years, (Schweckendiek and Doz, 1978). He postulated that this would allow for good growth of the maxilla and good speech development.

The goals of palatoplasty are to provide an intact hard and soft palate to create a normally functioning velopharyngeal mechanism as early as possible without hazard to other aspects of health and development, (Bardach et al., 1984). Two

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major criteria noted by these authors by which success of cleft palate surgery is determined are subsequent speech development and facial growth. Discussions about the timing of cleft palate surgery are focused on the need of early palatoplasty for speech purposes and late palatoplasty to ensure undisturbed facial growth are reported. A joint study between the University of Iowa and Dr Schweckendiek in Marburg, West Germany was published; The Marburg Project. In this study 43 subjects, 26 males and 19 females, were evaluated. All subjects had a veloplasty and lip repair at a mean age of 8 months and a delayed hard palate closure at a mean age of 13 years. Schweckendiek operated on all subjects. The range of age at delayed hard palate closure was from 8 to 22 years! None of the subjects wore an obturator between the primary veloplasty and the delayed hard palate repair. Examination procedures included clinical examinations, photographs, dental impressions, lateral cephalograms and tape recordings. The evaluation was based on the structural and functional aspects of the oral, nasal and pharyngeal regions. Length and mobility of the soft palate and movements of the pharyngeal walls were judged subjectively on the basis of repeated observations. Examination of the palate revealed that 74% of patients had a short palate with lateral scar bands present. Poor movement of the palate was found in 46% and 11% had a totally immobile soft palate. Facial growth was analysed from the cephalometric data, revealing that the entire maxilla and mandible were slightly retruded but within the non-cleft range. Skeletal analysis showed facial

growth was normal or close to normal in 88% of subjects. Speech evaluation was evaluated by a speech pathologist that was not fluent in German and so had particular difficulty in reliably validating the German speech sample. The speech results demonstrated that half of the sample had nasalized speech associated with velopharyngeal dysfunction. These findings may be attributed to the surgical technique for veloplasty used by Schweckendiek irrespective of surgical timing. Suturing together the soft palate under tension without first dissecting the mucoperiosteal flaps at the posterior edge of the hard palate may result in a shortening of the soft palate. The authors concluded that on examination there was an unusually high incidence of short palate, poor mobility of the soft palate and of velopharyngeal incompetence. Facial growth was found to be highly acceptable in the majority of patients. Thus delayed hard palate closure has been recommended to achieve good facial growth but authors have noted the deleterious effects on speech, (Slaughter and Pruzansky, 1954; Schweckendiek and Doz, 1978).

This study examines the timing of delayed hard palate surgery. The timing of the surgery was performed from age 8 to 22 years. Pooling this data confuses the growth outcomes and the authors' conclusion that the facial growth is highly acceptable may be due to the fact that some of the subjects are still growing. Further study into the same cohort when all subjects are post pubertal may have supported their findings.

Significant morphological changes occur in the maxilla as a result of the cleft palate repair, (Ross and Johnston, 1978). The posterior width of the maxilla narrows and the anterior of the maxilla has very little bony support and collapses after palate repair. This is in agreement with McCance. (McCance et al., 1990) (Ibid page 12) Ross notes the immediate effects of surgical reconstruction of the lip and palate is, on the whole, extremely beneficial. Aesthetics are greatly improved. The surgery introduces morphological changes, which almost invariably have a deleterious effect on facial development. However he concludes that it is the palatal surgery that causes the long-term deleterious effect on facial growth.

In a subsequent study the timing of palate repair was investigated, (Ross, 1987d). Palatal surgery timings were placed into five groups. The early group who had palate repair at 11 months or under, medium group who had surgery 12 to 20 months. Late palate repair was 21 to 33 months. Delayed hard palate closure between 4 years and 9 years of age and an unoperated group who had early soft palate repair but none had hard palate closure more than 1 year prior to the cephalogram being taken. In this paper the unoperated group all had had lip repair, early soft palate repair and the hard palate repaired when they had their radiograph taken! The term unoperated is often used within the literature. It is only upon investigation that one discovers that surgery has already been performed. The overall conclusion lead to no significant difference in facial

growth related to the age of the hard and soft palate repair being observed. The early repair showed slight advantage over the medium and delayed hard palate repair, with the late repair group having the worse results. Ross concludes '*this study demonstrates rather clearly and conclusively that facial growth is not the issue but that early repair provides better facial growth than the delayed hard palate repair.*' The study incorporates subjects who were operated on by different surgeons with altered surgical protocols across 15 centres. The conclusions from this cross-sectional approach are of limited value. This cohort consisted of subjects with a mean age of 11 years old in the delayed hard palate group directly compared with a mean age of 19 years for the unoperated group, which had all had palatal closure. Direct comparison between two such obvious pre and post pubertal groups only leads to questionable conclusions. These conclusions are contrary to what others have reported, (Mars, 1993).

Another paper in his series describes the different surgical techniques of palate repair, (Ross, 1987e). The inhibition of the posterior maxillary vertical development was seen in the early repair of soft palate subjects only. While in the hard palate subjects the forward translation of the maxilla and the forward development of the dentoalveolar process was inhibited. No significant difference was reported on the techniques when the hard and soft palate was repaired in one stage or two.

In his last part in the series on treatment variables affecting facial growth in complete UCLP Ross discusses the overview of treatment and facial growth, (Ross, 1987f). Basic intrinsic deficiency in the mid-facial skeleton was found in the UCLP males. Differences between surgical methods were analysed; cleft lip repair was primarily a cosmetic procedure but the lip repair can cause mild inhibitory influence on the long-term growth of the maxilla. Early repair of the alveolar process in infancy causes unfavourable growth without offering any apparent advantage over later repairs. Hard and soft palate repairs provide the greatest potential for inhibiting the maxilla in length, forward translation and posterior height. Ross' overall indication from a very in-depth series into treatment variables affecting growth concludes that the simplest treatment is as effective as any other. A complex procedure that necessitates multiple surgical and orthodontic procedures does not necessarily lead to a better facial growth outcome, (Ross, 1987a).

It would appear that the sole reason for preferring the two-stage palate repair procedure over the early one stage procedure is the presumed beneficial growth response, (Witzel et al., 1984). In this paper the authors agree that an unoperated palate results in excellent skeletal relationships and a hard palate repair delayed past 12 years produces excellent skeletal relationships, the data regarding repair between the age of 4 and 8 is contradictory. However, the effect on speech

development has to be considered concurrently with the timing of delayed hard palate closure.

Facial growth and speech are both important outcome measures in cleft lip and palate subjects. Often one outcome is studied without consideration of the other. Treatment regimens are recommended according priority to the eventual outcome for either speech or growth. Thus delayed hard palate closure has been recommended to achieve good facial growth but authors have noted the deleterious effects on speech. (Slaughter and Pruzansky, 1954; Schweckendiek and Doz, 1978; Hotz et al., 1978) However, very few papers have investigated that the effect of any surgical intervention before puberty may be responsible for the mid facial growth problems. Clinically these problems are only seen during and after the pubertal growth spurt, when the mid-facial profile becomes retrusive.

5.3   Vomer Flaps

The vomer flap facilitates early separation of the oral and nasal cavities at the lip repair operation. The septal mucoperichondrium is elevated and sutured to the mucosa of the sidewall of the nose. A single layer closure of cleft alveolus and nasal floor using a vomer flap, not only through the alveolus but also a large proportion of the hard palate at the time of the lip repair,(Sommerlad, 2001; Watson et al., 2001).

Several authors have discussed the use of a vomer flap. On the longitudinal data from Oslo Semb reports on possible growth retarding effects of a vomer flap, (Semb, 1991). More favourable growth in patients treated without a vomer flap is also reported, (Friede and Pruzansky, 1972). However this is not a common finding in the literature. Centres not using a vomerine flap and those where vomer flaps have been used showed similar results.

Raising vomer flaps at the same time as the lip closure is a popular surgical technique. The effect on facial growth is still largely unclear, however good facial growth outcomes have been reported, (Sommerlad, 2001). There is no doubt that having performed a vomer flap earlier the task of closing the reminder of the hard palate is an easier less invasive technique. The vomer flap facilitates early closure of the oronasal defect, while conventional palate repair involves the raising of two large flaps to close the palatal defect.

In the facial growth study of patients with BCLP treated by the Oslo team the influence of the vomer flap is discussed, (Semb, 1991). Patients with BCLP initially had primary combined lip/vomer flap closure performed on both sides in a single operation from 1953. At the beginning of 1962 the closure has been done in two stages and the palatal repair between 3 and 4 years. The two stages were to avoid bilateral subperiosteal soft tissue stripping and vascular deprivation, to avoid interference with tooth and bone development. In Oslo the age of palatal repair was then gradually reduced for 4 years down to 18 months. Current

practice in the Oslo team is to perform the two stage straight line and vomer flap at 3 months with a von Langenbeck palate repair at 18 months. In this paper it is noted that the possible growth retarding effects of vomer flaps has been discussed by several other authors, (Friede and Pruzansky, 1972; Enemark et al., 1990; Friede and Enemark, 2001). However, in her paper Semb showed that centres not using vomer flaps have showed similar results to those where a vomer flap has been used. The Oslo team have found the use of the vomer flap to be clinically significant. In their opinion use of the vomer flap provides early separation of the oral and nasal cavities without artificial obturators, few fistulae, acceptable arch forms and a good foundation for mixed dentition alveolar bone grafting, (Bergland et al., 1986).

6. Variations in Surgical Outcome

The outcome of surgery is variable between different centres undertaking cleft lip and palate treatment. Many factors contribute to such outcomes; the timing of surgery, the competence of the surgeon, the nature of surgery and the extent of the original defect are some of the factors that may influence the treatment outcome.

According to one author the overwhelming conclusion was that it was the surgeon performing the procedure rather than the specific technique that affected facial growth, (Ross, 1987e).

In the first cross-centre study between Great Ormond Street, London, GOS and Oslo, cleft lip and palate outcomes from the two centres were recorded. Dental arch relationships of UCLP subjects were assessed using the GOSLON Yardstick, (Mars et al., 1987). The GOSLON Yardstick rates the dental arch relationship on dental study models at 12 years old. The GOSLON Yardstick comprises of 5 groups; group 1 & 2 represent a good maxillary/mandibular arch relationship with a positive overjets, group 3 is acceptable but tending towards an edge to edge incisor relationship and groups 4 & 5 have reverse over jets and poor facial growth outcomes. The results of this first cross-centre study showed the UK to have more UCLP subjects in groups 4 & 5.

Cross Centre Studies,
Oslo   GOS

GOSLON Grouping   **GOSLON Grouping**
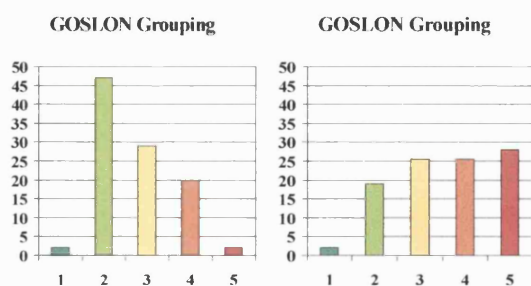
Further cross-centre studies within Europe highlighted poor facial growth outcomes in the centres from the UK. Dental arch relationships in the six centre International study were analysed and ratings performed on 149 complete UCLP dental study casts.

1992 Eurocleft Study

GOSLON Grouping
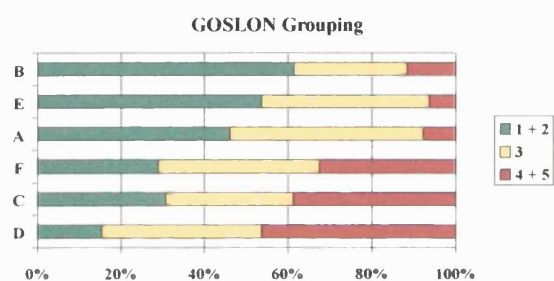
In the same six-centre International study of treatment outcome in unilateral cleft lip and palate the different surgical techniques undertaken in each unit and their timing are highlighted, (Shaw et al., 1992; Shaw et al., 2001a). Analysis of 151 cephalograms across the six centres, examined approximately 25 consecutive cases from each centre. Only one centre showed notable statistical differences in skeletal profile compared to the others, the statistical differences being in the soft tissue changes. True comparison is difficult because of the variation in treatment protocol at each centre. The variation in timing of surgery, use of pre-surgical orthopaedics, delayed hard palate closure and orthodontic treatment, highlight

the problems of methodology used, confounding significant differences between the six centres.

Two centres demonstrated especially poor results requiring a high percentage of late major revisionary surgery for mid face retrusion. Both these poor centres were British. Three centres had satisfactory results with different timing for surgical intervention and surgical techniques. Two centres showed little mid-face retrusion.

Many factors influence the growth pattern, including surgery, surgeon and type of operation as highlighted, (Enemark et al., 1990).

There has for some time been great controversy in the UK about which surgical factors have the most detrimental effect on facial growth. In the UK, cleft lip and palate surgery is generally complete in early infancy, and the experience of severe mid-face retrusion is common in the mature adult. The Clinical Standards Advisory Group (CSAG) was commissioned by the U.K. Health Ministers to advise on the clinical care for children with congenital cleft lip and palate. A national study of care and outcomes in children born with UCLP was performed over a 15-month period, (Sandy et al., 2001). Two cohorts of children aged 5 years and 12 years were examined. There were 57 active cleft teams in the U.K. at the start of the 15-month period. The results of the CSAG study were disappointing with variable standards of care across the U.K.

UK CSAG Study 1998

5 Year Index

UK CSAG Study 1998

GOSLON 12 Years
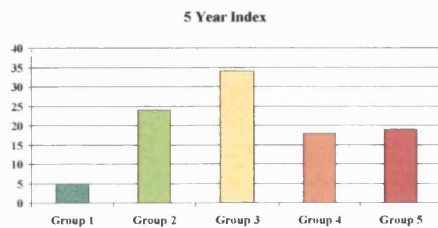
57 cleft teams took part in the CSAG study; each centre on average had 12 - 14 new referrals to the cleft team in 1995. The 57 cleft teams had 75 surgeons performing cleft surgery in the centres. Less than half of the surgeons performed one operation per year; only 10% of the surgeons performed 5 or more cases of palate repair or alveolar bone grafts annually.

Cleft Centre	Surgeons	Palate Repair
NTE	1	54
B	1	54
A	6	11
E	6	17
F	7	7
C	10	6
D	12	7

Recommendations from this study were made to the Department of Health. As a result of this study the UK Health Department recommended that the expertise and resources of the 57 active cleft centres are concentrated in 8 – 15 centres nationally. Thus enabling good quality, high volume cleft centres to provide the best possible care for their cleft lip and palate patients, (Bearn et al., 2001; Williams et al., 1994; Williams et al., 1996).

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7. Facial Growth Parameters and Analyses in Cephalometrics

Variations occur in the magnification of radiographs, cephalometric points measured, the line of superimposition, angular versus linear measurements and which points are most relevant to measure facial growth outcome.

Magnification of the radiographs has to be taken into account so that all measurements can be accurately compared between several different years of data collection and between different centres. There are different schools of thought on the points that move during growth and those that are stable throughout the whole translocation of the maxilla.

One author defines the translocation of the maxilla, describing the bone deposition and reduction to achieve the downward forward movement of the maxilla, (Enlow and Hans, 1996). The growth of the cranium and surrounding structures is analysed by measuring skeletal points and reference planes to note the rotation, change in angle or length and enables cross-examination of the relationship of skeletal structures during growth periods.

The lateral skull radiograph is widely recognized in the literature and cephalometric programs enable these complex movements to be measured, (Turner and Weerakone, 2001). Selection of the cephalometric programs or the digitised points and angles to be used as reference vary. Authors have analysed

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the findings but given different interpretation to which points show craniofacial growth making true comparison between papers difficult.

A number of the following articles agree that their studies on the cranial base in the cleft population have found them to be the same as the control population for angular measurements but smaller in linear dimensions.

Facial growth in children with complete BCLP is reported in a cephalometric study, (Narula and Ross, 1970). A random sample of 67 children, 30 subjects at 6-year old were chosen because of their maxillary deformity, 25 subjects between 6 and 12 years, and 19 subjects at 12 to 16 years. All male and females were age and gender matched with a control sample. The surgery protocol varied with lip repair between 2 to 8 months and palate repair at 13 to 48 months. The 30 6-year olds were compared with the control sample; the overall anterior-posterior length of the maxilla was found to be longer in the cleft cases. The author noted that the forward positioning of the premaxilla and the convex facial profile showed the most significant difference, when examining the antero-posterior length in the samples. During the growth period from 6 years to 16 years the overall jaw relationship and profile reduced in the cleft group. The author concluded that the premaxilla was very prominent at 6 years in children with clefts but in the normal growth range by the age of 16 years.

Cephalometric evaluation of facial growth in operated and unoperated patients with ICP is reported, (Bishara, 1973). The antero-posterior craniofacial relations

of growth found that isolated cleft palate only subjects have relatively posterior

relationships to the cranial base. No significant differences were found between

the maxilla and mandibular relations (ANB and NaPg) in the cleft or non-cleft

samples. This author reported further studies into cephalometric comparisons in

India and Mexico, (Bishara et al., 1978; Bishara et al., 1986), finding that the

early protrusive premaxilla was near normal after puberty. He noted that the steep

mandibular plane and an obtuse gonial angle in the cleft patient lead to a long

lower face height. Comparisons between the Mexican cohort and Indian cohort

illustrated that the Indian normal skeletal pattern is more protrusive than the

Mexican skeletal pattern. Skeletal differences demonstrated in these studies the

intrinsic cleft palate growth tendency within different racial populations.

Craniofacial growth between different cleft types was reported in a mixed study,

(Krogman et al., 1982). This study included 64 UCLP, 32 BCLP and 78 ICP

subjects. Lateral skull and antero-posterior (P-A) cephalograms were analysed in

three groups, birth to 1 year, 1 to 6 years and 6 to 10 years. The findings were that

cranial base achieved 90% of the adult growth value by mid-childhood. Cranial

base differences were noted in the BCLP subjects in comparison to the UCLP

patients. Another finding was that in the female BCLP subjects a larger sella angle

and a longer lower facial height was found. Larger gonial angle, mandibular length

and ramus height were noted for the whole BCLP group. Reduced posterior face

heights were noted across all cleft types. The authors concluded that the BCLP

group were the most severe cleft type and that the angles exhibited were of a compensatory nature.

In only one reported study was it noted that the angles SNA & ANB were different in males and females, (Filho et al., 1998). Most literature pools the data for males and females in angular measurements and only separates some of the linear measurements.

Craniofacial analysis of 19 UCLP and 9 BCLP subjects looked at the age of palatal surgery and the effect on facial growth, (Johnson, 1980). Early lip repair and palate repair at 1 year was examined. Two groups were studied, the younger group of 13 to 15 years and the older group of over 15 years of age. Cephalometric analysis was performed, however this is the first paper to note that the anterior nasal spine (ANS) was difficult to digitise in the cleft patient. ANS point was used as the most anterior point of the maxillary basal bone, noting that the difficulty of locating points affected by the inherent cleft deformity. The study of the two groups noted the lack of growth during the mid-face development in both horizontal and vertical dimensions. In the UCLP subjects the mandible accentuated a lack of mid-face growth by over compensating. The increased lower facial height illustrated the lack of mid-face advancement. The BCLP subjects in comparison with the controls experienced decreased mid-face development but had normal posterior facial height. Within the 2 groups

(younger and older group) no significant differences was shown between the sexes so the data was pooled.

Disagreement exists within the literature about the preferred line of superimposition, with some authors using Sella – Nasion, while others use Nasion - Basion. Superimposition on Frankfort plane, Pterygomaxillary vertical plane or anterior cranial base is also published, (Formby et al., 1994). The different lines of superimposition may alter the relationships of angular and linear measurements, which in turn make cross-examination of results very difficult.

Maxillary growth in children having undergone Delaire's functional cleft surgery is reported. Cephalometric analysis and study model measurements were assessed on 10 cases that had Delaire's lip and palatoplasty, (Adcock and Markus, 1997; Markus and Precious, 1997). Method error and standard deviation of errors was assessed by Dahlberg's formula. The architectural and structural craniofacial analysis of Delaire's enabled any effects of cleft lip and palate surgery to be assessed against the 'child's inherent skeletal predisposition'. A 'non-functional cleft surgery group' was used as one comparison and a non-cleft sample as the other group. No significant differences were noted in cranial base disposition or maxillary arch widths. Markus concluded that the facial type is different in the cleft and non-cleft population, with the vertical maxillary heights of the non-cleft and cleft groups being closely correlated, although these findings were not shown in his results. Nowhere in this paper is the rationale of Delaire's functional cleft

surgery protocol outlined or an explanation of assessing the child's inherent skeletal predisposition. In this paper there is no indication of the age at which the lip or palate repair was performed and the paper investigates a very young cohort of 6 years old. The authors introduce this paper by saying *'whatever parameters are used should be simple and easy to measure accurately.'* The cephalometric analysis is then based on the Delaire measurement technique, a seldom used and complicated system. If a comparison with accepted cephalometric analyses had been included the paper may have had more meaning. The assessment of the child's inherent skeletal predispositions can only be utilised if control populations of the same racial and skeletal backgrounds were available.

Cephalometric studies in a previous Mexican study used Downs and Mayne analysis for Control models, (Ortiz-Monasterio, 1959; Ortiz-Monasterio et al., 1966). In the 1966 paper cephalometric studies were made in a group of 300 normal non-cleft children aged 1 month, 1 year and 5 years. The results were similar to those of Downs, Mayne, Brodie, Broadbent and Subtelny (Downs, 1948; Downs, 1956). The only noted difference was a larger angle of convexity for the Mexican series. Although obviously more growth is to come and more facial growth disparities may become apparent. This study highlights that different racial groups do have different skeletal variances however small the differences. This group of papers reinforce the need for control data to be from the same racial population.

8. Effects of Pre Surgical Orthopaedics and Orthodontic Treatment

Within the literature there seems to be great advocacy for the use of pre surgical orthopaedics and great scepticism of its clinical benefit by others.

Separate studies on arch dimension and facial growth of patients with BCLP have been reported. Facial growth in patients with BCLP studied cephalograms, (Heidbuchel et al., 1994; Heidbuchel and Kuijpers-Jagtman, 1997). This multi-centre study between Nijmegen and Oslo examined the differences in facial growth. Nijmegen used pre-surgical orthopaedics routinely and surgical setback of the premaxilla. Oslo used no pre-surgical orthopaedics and no premaxillary setback. Sagittal facial growth of 21 subjects between 6 and 20 years old from Nijmegen formed the sample. Documented retrospective control studies of 90 bilateral cleft lip and palate patients from Oslo were used as the comparative growth data sample. The measurements were digitised from 131 lateral skull radiographs. The timing of surgery was different between the two centres. Nijmegen used presurgical orthopaedics prior to lip closure at 3 months combined with delayed hard palate closure at 4 years of age with surgical setback of the premaxilla. Oslo used lip and vomerplasty at 3 months and posterior palatal closure at 6 months, no presurgical orthopaedics or premaxillary set back procedures. Results showed that the mandibular growth was similar between the two centres with slight statistical differences noted in the premaxillary region,

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which were retroclined in the Nijmegen study. The only significant statistical difference between the two centres was seen in the soft tissue profile. In the Dutch sample the soft tissue profile was found to be more convex. The author concludes that, as the facial growth was similar between the two centres that no detrimental growth effects could be attributed to the osteotomy of the premaxilla. Statistical differences were noted in the retroclined premaxillary region of the Nijmegen sample but the conclusions showed no evidence of detrimental growth effects. The results and conclusions were confused in this paper. Variation in treatment protocols between the centres made direct comparison of detrimental growth effects difficult.

Aesthetic and functional outcomes of surgical and orthodontic correction of the bilateral cleft patient are reported, (Gaggl et al., 1999). This study examined 20 adults, (19 – 23 mean age 21.4 years) who had been operated on as children and followed up as adults. Cephalometric analysis and morphology of dental study models is discussed. Pre-surgical orthopaedics with a two-stage lip closure, late hard palate closure and early orthodontic treatment was used. Findings indicate that the underlying skeletal irregularities remained unchanged in comparison to a control sample. Cephalometric analysis showed that in the bilateral subjects orthognathic surgery to the mid-face was necessary for the optimum correction due to the growth disturbance.

In his thesis Kramer examines the delayed deciduous tooth eruption in clefts with comparison to a non-cleft sample. This study examined the effects of Presurgical Orthopaedics (PSO) on arch depth and cleft widths, (Kramer, 1994). The cohort consisted of 139 mixed clefts, 13 CL only, 28 CLA, 50 UCLP, 23 BCLP, 25 ICP and 84 non-cleft subjects were investigated. The study consisted of three main groups, a 'before surgery' group, 0 to 3 months, an 'after surgery' group, 3 to 9 months and a 'during and after surgery' group, 9 months to four years. The conclusion was that the passive plates restrict palatal growth development. However no control PSO cleft group was used, the only group comparison being cleft or non-cleft. After lip repair a distinct influence on the anterior palatal region was seen. Anterior arch depth and cleft widths reduced in all cleft types. PSO apparently had prevented major palatal collapse after lip repair. After palate repair the arch depths were smaller in cleft children except in the BCLP group. The palate surgery was performed in two groups; some had the soft palate repair only while others had hard and soft palate repair. Data showed closure of the hard and soft palate in one operation had a significant impeding influence on the posterior sagittal palatal growth. The closure of the soft palate only had a minor restrictive influence. The paper is very heterogeneous with numerous groups, varied surgery protocols and confused conclusions.

Longitudinal studies on arch dimensions from Japan showed the effect of lip and palate surgery on facial growth on children from infancy to 4 years, (Honda et al.,

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1995). Dental casts of 95 children, 7 cleft lip and alveolus subjects, 52 UCLP subjects, 24 BCLP subjects and 12 cleft palate only subjects were used in this study. Elastic strapping was used to reposition the protruding premaxilla prior to lip surgery on the BCLP subjects. Comparison of the results between unilateral and bilateral cleft patients showed some moulding effects. The reconstructed lip, after lip repair forcibly moves the premaxilla into a new position prior to palate closure. This moulding effect is responsible for the increased posterior arch widths experienced in the UCLP and BCLP groups. This is in agreement with other studies highlighted earlier within this literature review, (Muthusamy, 1998). Narrow anterior arch widths and lateral displacement of the maxillary segments is reported in related papers, (McCance et al., 1993).

Changes produced by presurgical orthopaedics can successfully reduce the protrusive deformity of the premaxilla in the BCLP patient, (Robertson and Hilton, 1971; Robertson et al., 1977). Forward growth of the structure is restrained to allow the remainder of the maxilla to catch up.

Many papers discuss the facial growth and morphology of the cleft patient with the use of pre-surgical orthopaedics and/or orthodontic treatment during the growth and development of the patient. The reported literature from the 1950's notes orthodontic treatment being used as early as 3 years old, (Bauer, 1959). Many authors have routinely used a variety of pre-surgical orthopaedics,

orthodontic treatment, and surgical resection of the premaxilla, (Noverraz et al., 1993).

9. Control Population Studies

Populations differ not only in size and physique but also in the timing of the growth processes. There is substantial literature on the somatic growth differences between races and "in an ideal world all populations would have their own growth standard," (Brook, 1995).

Cephalometric comparisons in India and Mexico are reported, (Bishara et al., 1978; Bishara et al., 1986). The findings were that the early protrusive premaxilla was within a normal range after puberty. He noted that the steep mandibular plane and obtuse gonial angle in the cleft patient lead to a long lower face height. Comparisons between the Mexicans and Indians showed that the Indian normal skeletal pattern is more protrusive than the Mexican skeletal pattern. Concluding again that such differences are the intrinsic cleft palate growth tendency.

This study highlights that different racial populations do have different skeletal variances however small the differences. This is in agreement with other papers, (Ortiz-Monasterio, 1959; Ortiz-Monasterio et al., 1966).

The onset of puberty for males and females throughout the world is very different. The age of the female menarche is often used as a predictor for the start of puberty. However delays in the menarcheal ages are reported in the literature.

Somatic growth measures of 3960 girls were studied from three districts in Sri Lankan, (Balasuriya and Fernando, 1983). The nature of school selection was that children in Kandy and Jaffna were judged to be from a higher socio-economic background than those from Nuwara Eliya. Heights and weight measurements were taken and all girls asked to recall the onset of menarche. Results showed that the girls from Nuwara Eliya developed much later than those form Kandy and Jaffna. Mean ages at menarche were 13.8 years in Kandy, 14.7 years in Nuwara Eliya and 14 years in Jaffna. The lower socio-economic standard in Nuwara Eliya and associated poor diet was concluded to have contributed to the delay in menarche. Girls from Nuwara Eliya were 4 cms shorter and 2kg lighter than those from Kandy and Jaffna.

In a follow up study the effect of socio-economic factors on the age of menarche in Sri Lanka was investigated, (Jayasekara and Goonewardene, 1987). The sample comprised of 3967 Sinhalese girls from 8 to 18 years. Questionnaires were completed including information on their date of birth, age at menarche, father's occupation, family size and birth order. The mean age at menarche was 13.06 years. No significance between the father's occupation, family size or birth order was found. The earlier appearance of menarche, than in their previous study, was concluded to have significant impact on the educational, social and health policies of the country. The authors concluded that the earlier onset of menarche and

longer reproductive period demanded sex education might have to be introduced into schools earlier.

A large cross-sectional study by the World Health Organization on the menstrual and ovulatory patterns in adolescent girls is reported, (World Health Org., 1986). Multi-centre studies on the age of menarche studied 3073 girls. The median age for menarche was reported. Many papers have also investigated the onset of menarche to determine the stage of the female pubertal growth process.

Cameroon had a delayed onset of menarche at 14.27 years, (Pasquet et al., 1999).

Mexico had a mean age of 13.79 years, (Malina et al., 1977).

Oslo had a mean age of menarche of 13.3 years, (Liestol and Rosenberg, 1995). China's mean age was 13.2 years, (Hesketh et al., 2002).

India and North Carolina, USA at 13.1 years, (Adair, 2001).

France had a mean age of 13.05 years, (Crognier and Tavares Da Roche, 1979). Bangladesh had a mean age of 13 years, (Chowdhury et al., 2000).

Spain had a mean age of 12.9 years, (Marrodan et al., 2000).

In a recent paper the UK had a mean age of 12.8 years, (Cooper et al., 1996).

In the UK childhood growth and the mean age at menarche is reported to have been 16.5 years in 1840 but is now 12.8 years, (Cooper et al., 1996). The major contributing factor to this decrease in menarcheal age is concluded to be the

improved nutrition and socio-economic standards of the generations being passed down from mother to daughter over the years.

An interesting paper raises the question; " Is puberty getting earlier in the UK? " (Finlay et al., 2002). In this paper the opinions of Teachers, Doctors and Paediatricians is reported. Teachers from both primary and secondary schools voted by 73% that more pupils had an earlier onset of puberty. Doctors voted by 52% that the age of menarche was earlier than in the reported literature to date.

From these reviews it is clear that there is a huge range in the age of menarche throughout the world from Sri Lanka at 14.7 years to the UK at 12.8 years. It seems reasonable then that there may be variance in the somatic growth, skeletal variances and the timing and nature of facial growth between these different populations.

These articles strengthen the need for control data to be from the same racial background. This is in agreement with other authors. *The control patients must be of the same population for accurate correlation between racial backgrounds and skeletal variances',* (Ortiz-Monasterio, 1959; Ortiz-Monasterio et al., 1966).

10. Normal Somatic Growth & Facial growth.

The relationship between somatic growth and facial growth has been examined within the literature. Somatic growth charts and standard percentile growth curves provide information on the population's height and weight measures over time. Pre-pubertal and pubertal growth spurts are plotted with the population mean growth curve. Individual subjects can then be plotted against their own population mean growth percentile curves to assess their growth progress. A number of longitudinal studies have been published investigating the relationship between the peak velocities of facial growth and the peak velocities of general skeletal development. This literature reviews healthy non-cleft population somatic and facial growth studies.

A mixed longitudinal study of 51 subjects (26 males and 25 females) examined stature, head height and the vertical growth of the face, (Baume et al., 1983). Patterns of change during growth were determined from 663 cephalometric radiographs. Lower, mid and upper facial relationships were compared with stature and head height. Radiographs were taken annually from age 4 to 16 and one post-pubertal radiograph in adulthood. Between 9 and 13 radiographs for each individual formed the longitudinal data records. Analysis of variance, ANOVA, was conducted to determine any differences related to whether the subjects were male or female. Cross-sectional analysis of each facial component

in relation to stature and head height measure was examined. Longitudinal analysis results were expressed as a percentage of the stature and head height. The mean value for each facial component was calculated as a percentage of the mean stature and head height measures. Results showed that the overall facial growth of the face is larger in males than females. Vertical changes in facial growth were found to resemble the rate of skeletal growth.

In contrast to this the changes in mandibular dimensions and the relationship to standing height were reported in other papers, (Bishara et al., 1981). A cephalometric study examining the changes in standing height to five mandibular parameters comprising of 23 males and 15 females. The antero-posterior changes in size of the mandible were plotted annually from age 8 through to 17 years of age. In this study only two linear measures were compared to standing height, all other angles were to indicate change over time. Each parameter was examined for overall change from 8 to 17, the average change over the 9-year period and the maximum velocity of that change. ANOVA was used to detect sex differences, the growth profiles of incremental and absolute changes in standing height were found to be significantly different. Results were evaluated on the mean cross-sectional values for change and longitudinal growth values for each subject. In this comprehensive study Bishara found that: Growth change between standing height and mandibular measures had statistically significant sex differences. Growth profile of standing height in relation mandibular length was significantly

different for boys and girls. Mean ages for maximum and minimum growth increments were not significantly different between standing height and mandibular parameters for boys and girls, although ages for maximum and minimum changes were earlier in girls. Changes in standing height and mandibular length were found to be significantly different. Boys had greater change in both standing height and mandibular length but not for mandibular relationship. He concluded that the growth changes between mandibular length and mandibular relationship to standing height couldn't be correlated. The timing and magnitude of somatic or craniofacial growth is still highly unpredictable.

Late growth changes in the craniofacial skeleton examined serial data from cephalometric radiographs on over 20 adults, (Lewis and Roche, 1988). Data presented were radiographs taken from age 17 to 50 years on the 8 men and 12 women. Each patient provided 3 to 8 successive radiographs. Three cranial base lengths (S_N, Ba_N, Ba_S) and three mandibular lengths (Ar_Go, Go_Gn, Ar_Gn) were analysed. The authors found that the mean ages for the maximum-recorded length ranged from 29 to 39 years among the different dimensions. Varying degrees of 'negative growth' was indicated by successive slightly shorter measurements. There were small growth increments after age 17 until the maximum recorded value. There were then decreases in length recorded after the maximum value. The maximum adult growth rate for the six dimensions occurred between age 29 and 35 years with variable individual timing and rates of

growth. This is an interesting paper, as most somatic and craniofacial growth would have presumed to finish well before age 29.

In a mixed longitudinal study the craniofacial growth and skeletal maturation was evaluated on the bone maturity of hand wrist radiographs, (Arat et al., 2001). In this study subjects were grouped based on skeletal maturity and chronological age. The author believed that physiological criteria are more appropriate for evaluating craniofacial growth. Other authors support these findings, (Lewis and Roche, 1988). Some individuals were followed longitudinally but most were compared cross-sectionally. The groups were divided into three degrees of bone maturity. The mean ages within the three groups were 10.27 years for Group 1, Group 2 11.55 years and Group 3 14.79 years. The findings show that the mid-cranial base remained unchanged in all periods. The author notes that the mid-cranial base, Sella – Nasion, is known to complete its growth by age 10 and no change occurred in this dimension in this study. The posterior cranial base measurement, Sella to Basion, showed significant increases in all three groups. Dimensional increases in the posterior cranial base may be associated with spheno-occipital synchondrosis activity. This pronounced dimensional increase was highly related to its growth potential. Acceleration occurs in the growth of the cranial base during the pubertal spurt and this acceleration is closely related to skeletal age. This is a very interesting finding as this growth point is within millimetres of where the cleft palate repair is performed. In this study both

maxillary and mandibular basal dimensions increased. The increase in maxillary dimensions was not related to skeletal maturation; however, mandibular growth was found to grow in parallel to skeletal maturity. Facial heights increased and the vertical facial growth is related to skeletal maturation and somatic growth, other authors agree, (Baume et al., 1983).

A further longitudinal study into changes in the non-cleft adult facial profile is reported, (Formby et al., 1994). Longitudinal lateral cephalometric radiographs of 47 subjects (24 males and 23 females) formed this study. Radiographs were taken between the ages of 18 and 42 years, with a minimum of 3 radiographs for each patient. A relaxed lip posture and teeth in occlusion enabled good soft tissue and skeletal analysis. All subjects exhibited Class I molar relationships with no excessive protrusion or retrusion. The 50 lateral head radiographs were analysed for growth changes in group means and growth at an individual level. Both skeletal and soft tissue points were measured. Analysis of individual data revealed that most measurements showed significant changes in the group means. Great variability was also noted within individual growth curves. The skeletal measurements showed more statistically significant increases over time than the soft tissue dimensions. Soft tissue dimensions in the lip and chin areas had greater variation. In summary the results show that males increased more in posterior face height than females, changes in anterior face height were comparable between the sexes. Males were noted for becoming more prognathic and having a

straighter profile with age. Both sexes had increased nose depth and nose length over time. Male changes occurred before the age of 25 but females after the age of 25 the authors attributing this to the childbearing and hormonal changes that occur during this age period. Exclusion of radiographs outside the selected age ranges meant that only 15 of the 24 males and 10 of the 23 females fulfilled the age criteria, therefore 22 were then excluded from the original study cohort of 47 subjects. In their follow up paper the longitudinal growth changes in the sagittal relationship of maxilla and mandible is reported, (Nanda and Ghosh, 1995). Longitudinal cephalometric radiographs were taken at yearly intervals on 86 subjects (46 males and 40 females). The radiographs were taken at age 6, 12, 18 and 24 years. Incremental changes were evaluated between these four age groups. Results from this study showed that the female subjects exhibited less growth than the males in linear measures from the pterygomaxillary plane to A point, B point and Pogonion. Angular measures were not included in this study. Growth changes between the three periods of 6 - 12 years, 12 - 18 years and 18 - 24 years showed females to have the largest increase in the 6 - 12 period with males having the maximum increase between 12 - 18 years. Mean growth increments were larger at point B and Pogonion for males than in the female subjects. Mean growth changes only provide a group pattern and it is noted that the individual patterns do not necessarily follow this group pattern. Nanda & Ghosh conclude that *'prediction of growth patterns is a much sought after goal which still eludes us'*.

Differential growth of the upper and lower components of the face seems to be important in the development of different facial patterns. The developments of subjects with open and deep bite faces have been studied in detail in earlier papers, (Bishara and Jacobson, 1985; Nanda, 1988). The subjects were found to grow differently.

Post-pubertal mandibular and maxillary facial growth in females is reported, (Foley and Mamandras, 1992). The growth changes were investigated in 37 Class I females at ages 14, 16 and 20 years. This paper found that mandibular growth recorded over this 6-year period was significant and the mean mandibular growth was almost twice that of the maxilla. The rate of maxillary growth every two years was 0.5mm. However, the mean incremental linear values for posterior face height were not significantly greater than for anterior facial height. Mandibular plane angles decreased suggesting a tendency for closing rotation of the mandible. The author concludes that the significant findings in this study are tempered by the variability of mandibular growth and consequently they are still unable to accurately forecast post-pubertal mandibular growth.

In a mixed longitudinal study the vertical growth of the anterior face in 60 subjects is reported, (Ligthelm-Bakker et al., 1992). The subjects were participants in the Nijmegen Growth Study. Lateral cephalograms were taken annually between 7 and 9 years and biannually from 9 to 14 years with a post

pubertal record at 22 years of age. Body height and other anthropometrical data were collected with the cephalograms. The cohort comprised 32 females and 28 males, for whom 6 to 12 lateral cephalograms were available. To minimise biologic variability when considering growth rate, morphologic age was used instead of chronological age. As a measure of morphologic age, the percentage of mature height was used, assuming that the mature body height (100%) was attained at the age of 22 years, the post-pubertal radiographic point in this study. This assumption seems very dubious in light of this current literature review (see page 66). Plots of individual average growth velocity for a linear measurement of two representative boys were presented. Six linear measures are all that is presented in these results. In this study the main conclusions were that a negative correlation exists between the average growth rate of the upper and lower anterior facial height. This suggests that some children grow at a higher rate in the lower face than in the upper face and vice versa. The result of these differences is either the tendency toward an open bite or deep bite facial pattern. The author notes that an established anterior facial proportion is reinforced with further growth because of the differences in growth rates. Children who showed a fast growth rate of the upper anterior face height showed slower lower anterior growth rates, tending towards a deep bite. Children who exhibited slow growth of the upper anterior face height showed a faster lower anterior face height resulting in an open bite.

Assessment of the balance and harmony of craniofacial growth has been studied with some papers examining the relationship between the pre-pubertal and the pubertal growth spurt in skeletal maturation and the craniofacial maturation. As this review of the literature indicates the findings do not uniformly agree with regard the timing and predictability of growth spurts. Neither do they agree that facial growth has ceased or remains stable after puberty.

11. Catch up Growth

Growth is a complex multiphase process. Growth begins at conception with hormonal and environmental influences having the maximum effect when growth is at its fastest. During this prenatal period the effect and consequences of any intrauterine growth disturbances can be clearly seen in postnatal life. Evidence that poor nutrition in early life is an important factor on growth is increasing. In normal growth three principal phases of growth can be seen. Phase one is the rapid and rapidly decelerating growth of the first three years. Phase two is the steady and slowly decelerating growth of mid-childhood. Phase three is the growth of adolescence, (Brook, 1995).

Normal growth and development of the head and face is instigated by a set of interactive processes; appropriate levels of hormone, adequate nutrition combined with the correct genetic instructions form these processes. Hormones are secreted from glands in the embryonic pharynx, anterior pituitary, thyroid,

parathyroid and the thymus. These are multiphase effects, the anterior pituitary secretes trophic hormone for the gonads, adrenals and thyroid as well as growth hormone. Alteration in the level of hormones regulated by the anterior pituitary can be reflected in altered growth. General body growth reflects the same gene products and metabolic processes that govern growth of the head and face, (Bowers et al., 1987).

The whole concept of cleft palate feeding problems and subsequent growth lag and catch up growth is well documented. These problems include poor or inadequate suction, prolonged feeding time, frequent nasal regurgitation and aspiration during feeding. Hospital personnel often give initial feeding instructions with little experience in caring for infants with cleft lip and palate. The whole issue of cleft feeding and subsequent feeding difficulties has opened the way for numerous feeding strategies and a variety of complex feeding equipment. Specialised feeding bottles, teats and a selection of presurgical orthopaedic plates have been designed to counteract and overcome the haphazard, prolonged or incomplete feeding routines often experienced by cleft children and their parents. The use of presurgical orthopaedic plates has long been debated in the literature with no substantial random controlled trial to date can provide evidence of their efficacy for feeding or arch alignment. There is little evidence to support the theory of a feeding plate creating a seal, resulting in negative intra-oral pressure to facilitate a good suck – swallow pattern.

The relationships between low birth weights in cleft children, subsequent catch up growth phenomena and feeding issues are discussed in this section of the literature review.

In a cross-sectional study the general growth was measured on subjects aged 2 to 18 years of age, (Bowers et al., 1987). Measurements were taken on 252 subjects comprising 44 BCLP, 87 UCLP, 67 ICP and 20 ICL, the remaining cohort were craniofacial syndromic subjects. The subjects' heights and weights were compared with the population means at the National Centre for Health Statistics. Children with UCLP and ICP were found to be significantly shorter than their unaffected peers while the BCLP and ICL groups were found to show no statistically significant difference from the normal population mean. This finding led to the conclusion that the UCLP and ICP group present with an elevated risk for growth delay or deficit. No mention is made of any initial weight loss or feeding problems possibly this is due to the study only looking at the subjects postoperatively at age 2.

In a follow up paper the authors further examined 144 UCLP and ICP subjects, (Bowers et al., 1988). Their findings showed that the male UCLP group had lower heights and body mass index in childhood but caught up in adolescence. Females with UCLP were within the normal range until age 8 but then fall behind, however, the weight stays within normal limits. In the ICP group male ICP subjects are shorter than the male UCLP group, with the female ICP group

being shorter than their unaffected peers and the female UCLP group. This paper concludes that the ICP and UCLP subjects differ in growth from the normal population measures, but the nature and extent of the deficiencies differ between sexes and at different ages. Other authors also report these findings, (Schollaart et al., 1992).

In a study the parents of 37 children, 22 boys and 15 girls the weight records of cleft palate children during their first six months of life was surveyed, (Avedian and Ruberg, 1980). The median birth weight was at the 30th percentile, at 1 month the median had dropped to the 20th percentile. At month 3 and 4 the median was the 25th percentile. Only at six months old had the median weight returned to the original birth weight median of the 30th percentile. These figures clearly reflect the initial feeding problems experienced by these cleft children. In 12 of the 37 children at the age of six months their weights were still consistently well below normal without a return to an acceptable level; within the normal population range. One boy required hospitalisation for feeding problems at five weeks of age. The study does not follow these subjects beyond six months however; they conclude that the babies at least 'caught up to themselves' by six months. This paper highlights the initial weight loss due to cleft feeding difficulties experienced and show that most of the subjects had redressed this loss by six months of age. The authors concluded that early feeding instruction by an experienced cleft team would prevent the impaired weight loss and catch up pattern.

In a longitudinal sample of 279 cleft patients and serial control data, early lag periods in heights and weight levels were reported, (Ranalli and Mazaheri, 1975). 'Catch up' growth occurred in all cleft types, irrespective of cleft severity until about 3 years of age when compared to a normal non-cleft population height and weight scale. Clefts were grouped into five groups: ICP, UCLP, BCLP, CL/CLA and a control group. The sample of 279 subjects comprised 155 males and 124 females. Heights and weights were recorded on all subjects at six month intervals up to age two and then annually until age six. The results showed that sex appeared to be a factor for height and weight in the birth to 36-month period; however, this may reflect the improved nutrition post operatively. By the 36-month the males had caught up to the non-cleft population values for both height and weight and slightly exceeded the controls. At no time did the females exceed the norms by 36 months. In the female ICP and BCLP groups the 'catch up' did not occur until 60 months.

Overall this study indicates that the cleft children are born heavier and longer than the control sample but after birth they begin to show growth lag and weight loss. This lag can be attributed to early feeding problems, frequent upper respiratory infections and repeated hospitalisation for their cleft lip and/or palate surgery. An early lag period occurred but by 3 years most of the cleft children had caught up to the normal range, rebounding to growth equality, appearing to conform to the concept of the catch up growth phenomena.

In another paper direct measurement of heights and weights of 83 cleft children found that by age 2 most children had caught up to their non cleft population values, (Lee et al., 1997). This study although comprehensive in its protocol proved to be small in sample size, too varied in cleft type and included syndromes, which compromised the growth conclusions as it was not clear whether the results were as a direct consequence of their clefts, a manifestation of their syndrome or an endocrine insufficiency. The conclusions were that faltering weight pattern are commonly seen in children with palatal clefts, especially the isolated cleft palate group, all the cleft groups grew relatively poorly in early infancy but recovered, attaining both the expected weight and height for their population means by age two.

Further studies on the relationship of birth weight, body length and cranial circumference found severe growth retardation in the most pronounced cleft types, (Becker et al., 1998). Data was recorded from 2936 cleft subjects, 865 cleft lip only (ICL), 811 cleft palates only (CP), 1139 had cleft lip and palate (CLP) and 121 had Pierre Robin syndrome. Data was obtained from the Medical Birth Registry of the study subjects. Body dimensions in the ICL group were found not to differ from the control subjects, however, the infants in the CP or with CLP groups were found to be lighter and shorter than their non-cleft counterparts. Infants with BCLP had lower birth weights than the UCLP group. The authors found that 'intrauterine growth retardation directly increases the probability of

cleft occurrence or makes the cleft more severe', concluding that the more severe the growth retardation is, the more pronounced the cleft manifestation.

Catch up growth is one well-documented growth issue but another overwhelming problem is the early feeding difficulties experienced by both the newborn cleft child and their parents. These problems include poor or inadequate suction, prolonged feeding time, frequent nasal regurgitation and aspiration during feeding.

One paper evaluated the ESSR method of feeding by comparing weights of infants with cleft lip and palate and a control cleft lip and palate sample, (Richard, 1994). The ESSR method involved four stages: Enlarge, Stimulate, Swallow and Rest. Enlargement of the nipple allows the infant to receive more formula to the back of the throat. Stimulation of the teat in the mouth prepares the infant for feeding. To swallow the fluid normally the infant receives an adequate amount of formula without using excess energy. Resting at the end allows the infant to finish swallowing the formula already in the back of the throat thus avoiding gagging or nasal regurgitation. In this study the 69 cleft subjects were divided into an ESSR group and a control group. All patients in this study were fitted with a palatal appliance; this was standard practice for this team, not relied upon as a feeding device. The results showed greater mean weight gain in the plate and ESSR method of feeding group. More than 67% of the ESSR group had BCLP, which is often identified with complex feeding difficulties.

Both male and female infants on the ESSR method, irrespective of cleft type showed greater weight gain than those fed by traditional methods. This study had a well thought out protocol, good sample selection and the ESSR method proved to be a genuine aid to cleft feeding, (Hinojosa, 1995).

The failure of infants with clefts to gain weight adequately has been documented by several authors, (Avedian and Ruberg, 1980; Ranalli and Mazaheri, 1975). The introduction of the ESSR method showed greater median weight gain over traditional feeding methods, (Richard, 1994). There is increasing evidence to suggest that poor nutrition in early life may be an important factor in growth disturbances seen in later life, (Brook, 1995).
However if failure to thrive or no catch up growth has occurred by the age of 2 or in some papers by 5 years then perhaps attainment of normal limits for height, weight or body mass index can never be expected.

12. Malnutrition

Malnutrition, particularly at a period of especially rapid growth such as inutero has long standing effects. Subsequent influences of under nutrition in the first and second years of life or later in childhood leave a long-lasting complex growth problem. During childhood stature is determined by the size that an infant has reached by the end of the first year of life, which is partly determined by genetic

circumstances and influenced greatly by nutrition and the subsequent rate at which the child grows.

Nutritional status has a profound effect on Growth Hormone secretion. Malnutrition is a well-recognised form of reversible growth hormone resistance, which can be normalised with nutritional supplements. A malnourished mother is likely to give birth to a baby with low birth weight, while children with protein-energy malnutrition do not grow as well as others according to a recent report, (Fernando, 1998). This kind of malnutrition is an underlying cause of almost one third of the deaths among children under 5 years in Sri Lanka. Malnutrition is still a serious problem in Sri Lanka, (Rajapaksha and Siriwardena, 2002). Food insecurity is one of the major reasons for malnutrition in Sri Lanka according to the Dept. of Census and Statistics. Poor financial and physical access to food is responsible for the malnutrition and food insecurity. Drastic price increases of essential food commodities and stagnating or deteriorating incomes created poor financial access to food. The civil war from 1984 - 2002 in Sri Lanka has exacerbated the essential food and financial problems.

A recent survey of 16,000 Sri Lankan children found that only one quarter were properly nourished, (Popham, 2002). More than one third were suffering from third degree malnutrition, the level beyond which children exhibit distended stomachs and skinny frames. Supporting evidence from the National Peace Council indicated that only 4,863 children under 5 years out of a random sample

of 16,767 were within normal nutritional limits. 6,371 children had third degree malnutrition, 3,186 with second-degree malnutrition and 2,347 with first-degree malnutrition, (National Peace Council of Sri Lanka, 1998). According to this report diseases such as malaria cause malnutrition first, which is still prevalent in Sri Lanka. Secondary causes of malnutrition are by worm infestations and thirdly by a lack of food.

Other authors hold these views, (Fernando, 1998; Country Strategy and Program Update 2002 - 2004, 2002; Brink et al., 1978; Anderson, 1975).

In another supporting paper it was found that Sri Lankans' require a calculated average of 2,260 calories per day. Availability of protein has gradually increased; nevertheless a high incidence of malnutrition exists with 60% of children under 5 suffering from malnutrition, (Rajapaksha and Siriwardena, 2000; Fernando et al., 2000). Poor growth of pre-school children, high rates of low birth weight babies, poor maternal nutritional status and micronutrient deficiencies are common nutritional problems in Sri Lanka.

To measure quality of life in a nation, the United Nations Development Program started figuring a Human Development Index (HDI). A nations HDI is composed of life expectancy, adult literacy and gross national product per capita. There are vast differences when comparing or studying a different ethnic culture. The HDI for the UK is ranked as number 13 out of 130 nations. Sri Lanka is

ranked at 79 much lower than the UK, the comparison between the two

countries are shown in Table 2.1 UK and Sri Lanka Human Development Index.

Table 2.1 UK and Sri Lanka Human Development Index.

	UK	Sri Lanka
Life Expectancy (years)	77.7	72.1
Total Population (millions)	59.4	18.9
Annual Population (growth rate)	0.1%	0.8%
Population under age 15	19%	26.3%
Under nourished people	0	23%
Children under weight for age	0	33%
Children under height for age	0	17%
Infants with low birth weight	8%	17%
Malaria cases (per 100,000 people)	0	1,111

(United Nations Development Program, 2002; Rajapaksha and Siriwardena, 2000)

Nutrition or subsequent malnutrition is only one environmental factor that can leave a long-lasting complex growth problem. Emotional deprivation also has a profound influence on the growth process and may interact with the provision of food, (Brook, 1995). A well-loved child is fed and nurtured, whereas a child with no prospect of a job or marriage or a burden may not be. Children need a good emotional climate to thrive. The mechanism of the effects of emotional deprivation on growth is not well documented but is linked to reduced growth hormone secretion and its associated growth failure.

Chapter 3

A) SUBJECTS AND METHODS

Introduction

The Sri Lankan unoperated and operated BCLP subjects are investigated in a retrospective cross-sectional and longitudinal study. The term unoperated shall refer to subjects having had no previous surgery to either the lip or the palate. Very few reports on the older and mature unoperated cleft patient and subsequent follow-up after surgical closure are reported. In this study no pre surgical orthopaedics or orthodontic treatment was performed on any subject.

The discussion and results of this cephalometric study will be compared to the Sri Lankan control population. This is in agreement with other authors. *'The control patients must be of the same population for accurate correlation between racial backgrounds and skeletal variances'.* (Bishara et al., 1986; Ortiz-Monasterio et al., 1966)

Study Aims

1. To study the natural history of the unoperated subject.

2. To form non-cleft Sri Lankan population normative facial growth parameters (Controls).

3. To analyse the effects of lip surgery on facial growth and morphology.

4. To analyse the effects of palatal surgery on facial growth and morphology.

5. To analyse the effects of different timing of palatal surgery on facial growth and morphology.

Selection of Subjects for Study

The Sri Lankan Cleft Lip and Palate Project was the inspiration of Dr M Mars in 1984 and has become one of the world's largest databases in the cleft lip and palate field.

Subjects were selected for study after examination in Galle, Southern Sri Lanka or Kandy, Central Sri Lanka in 1984, 1985, 1986 (twice), 1990 (twice), when surgery was performed as well as follow-up records. Follow-up records only were collected in 1995, 1998, 1999, 2000 or 2002.

In Galle subjects responded to newspaper notices announcing the arrival of the British Team four weeks prior to the expeditions. Sri Lankan colleagues of the local Professor of Paediatrics also directly referred subjects. Other patients were 'picked up' by the Professor and British Team members at bus stops or in the market place! On the first major expedition, November 1985, over 1000 replies were received, including more than 400 subjects with conditions totally unrelated to cleft lip and palate.

Subjects presented at all ages from birth to old age, with every possible type of cleft lip and/or palate. In addition there were patients who had received lip but not palatal surgery, as well as patients who had received lip and palatal surgery performed in infancy by Sri Lankan surgeons. Subjects who presented with syndromic features received surgical treatment but were not recalled for the longitudinal follow-up.

This study is based on 81 complete bilateral cleft lip and palate (BCLP) subjects from birth to 55 years of age. The subjects form a subgroup from over 700 patients of all ages and all cleft types recorded in Sri Lanka.

These BCLP subjects have been divided into three main subgroups according to their surgical experience:

1. Those who have had no surgery: the unoperated subject

   (UNOP)

2. Those who had received lip surgery by the British surgeons but not palatal surgery: post lip repair   (POSTLIP)

3. Those who had received lip and palate surgery by the British surgeons: post lip and palate repair   (POSTPAL)

Subjects

This is a mixed cross-sectional and longitudinal retrospective study comprising 92 subjects at the outset.

The BCLP study cohort comprises:

   76 BCLP subjects from Galle, Sri Lanka

   16 BCLP subjects from Kandy, Sri Lanka

   92 BCLP subjects in total.

Of these 11 subjects were excluded leaving 81 subjects in the study.

Exclusion Criteria were:
1. Subjects on whom no radiographs were available. (N=9)
2. Anatomical anomalies or syndromic features that became apparent during subsequent examinations. (N=2)

Each subgroup has been age and sex matched with Sri Lankan non-cleft subjects to produce a standard deviation score. A full account of this process is given in Chapter 3 B) Statistical Methods.

Formal ethical approval was obtained from the University of Ruhuna, Galle, Sri Lanka and through the Research & Development Office in the Institute of Child Health, University of London in 1990. Approval was granted in 1990 for an indefinite period, for the duration of the Sri Lankan Cleft Lip and Palate Project. This approval was required for all non-treatment related radiographs, which form part of the longitudinal follow-up records for both the Cleft Lip and Palate subjects and the Control subjects. Formal ethical approval was only sought from 1990 onwards because in previous years all radiographs taken were related to the provision of treatment. In Sri Lanka there was and still is no formal process for consent for surgery or records. It is presumed that patients submitting themselves for surgery having had a consultation give their consent (indeed even in the UK formal consent to provide orthodontics, dental restorations and even extractions under local anaesthetic does not always involve formal consent with signature). Further comment regarding the ethical approval for non-treatment related radiographs is discussed in Chapter 6 Discussion and Conclusions.

Details of the composition of groups studied by age, sex and surgical experience are provided in Table 3.1. The age used is the age at which the British Team saw the patient and the age at which the first British records were taken. The age at which each patient had his or her palatal surgery is recorded in Table 3.2.

| | UNOP | | POSTLIP | | POSTPAL | | CONTROL | |
	M	F	M	F	M	F	M	F
Sample Size	11	7	17	5	32	14	238	259
Mean age	23.1	22.8	18.4	14.0	14.6	14.1	15.0	13.8
Age Range	6 - 49	9 – 55	8 – 38	4 - 24	4 – 50	8 – 28	6 – 30	6 - 30

Table 3.1 Groups studied by Age, Sex and Surgical experience.

The same patient may have radiographs, after subsequent surgical intervention, in the UNOP, POSTLIP, and POSTPAL sections.

Cross-sectional analysis examines the unoperated subject and the presenting facial growth attributes with no surgical intervention whatsoever. Cross-sectional analysis also examines the post lip repair group, those who have had lip repair only, to determine the effect of surgery, if any, on facial growth.

Longitudinal analysis examines the post palatal repair group. All subjects in the PostPal groups have had lip and palate repair. The data is subdivided into groups according to the age at which palatal repair occurred. Five groups encompass a variety of palatoplasty timing.

The five PostPal subgroups comprise:

1. Early palate repair in infancy - under 2.5 years of age.

2. Late palate repair - between 2.6 and 5 years.

3. Pre-pubertal hard palate repair - between 5.1 and 10 years.

4. Pubertal hard palate repair - between 10.1 and 18 years

5. Post-pubertal hard palate repair - over 18 years of age.

The age range and mean ages of five PostPal subgroups are shown in Table. 3.2.

| Years	POSTPAL 0 – 2.5		POSTPAL 2.6 – 5.0		POSTPAL 5.1 – 10.0		POSTPAL 10.1 – 18.0		POSTPAL 18 +	
	M	F	M	F	M	F	M	F	M	F
Sample Size	4	3	12	5	6	2	6	3	4	1
Mean age	1.66	1.9	4.3	4.6	7.6	8.7	13.5	13.7	26	21.25
Age Range	9/12 - 2.5	1 - 2.5	3 - 5	3.5 - 5	6 - 10	7 - 10	11 - 16	13 - 15	19 - 49	18.5 - 24

Table. 3.2 Post Palate repair (PostPal) subgroup by age at palatal surgery

Figures 3.2 to 3.8 inclusive show typical examples of subjects in separate groups: Unoperated subject, Post Lip repair subject and Post Palate repair subjects; under 2.5 years, between 2.6 – 5 years, 5.1 – 10 years, 10.1 – 18 years and over the age of 18 years.

Fig 3.1 Examples of the Reference Measurements
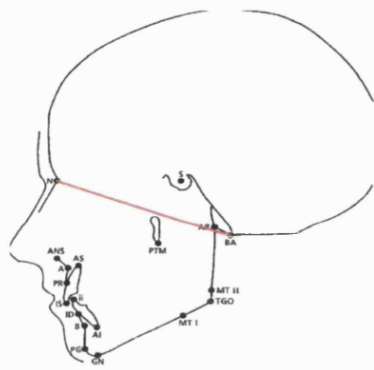
Ba_N - *Cranial Base*
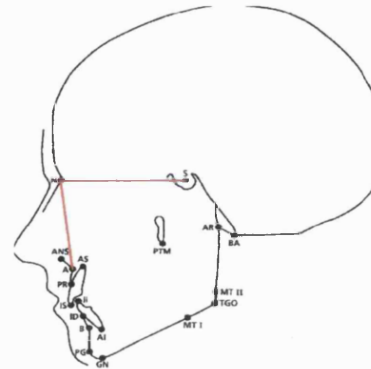
SNA - *Maxillary Protrusion*
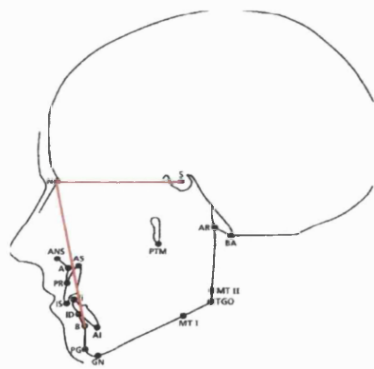
SNB - *Mandibular Protrusion*
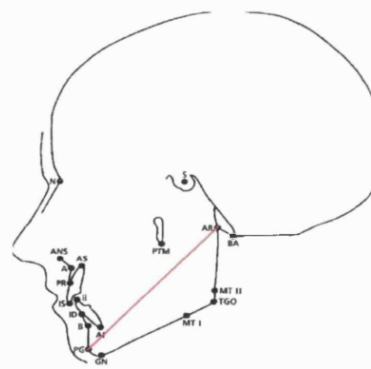
Ar_Pg - *Mandibular Dimensions*
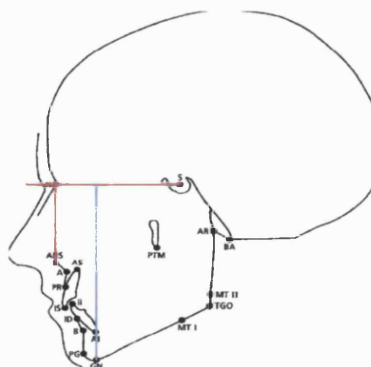
Facial Heights (Perpendicular Distance)

S_N_Ans - *Upper Anterior Facial Height*
S_N_Gn - *Total Anterior Facial Height*

Fig 3.2 Extra-Oral Photographs of an Unoperated subject
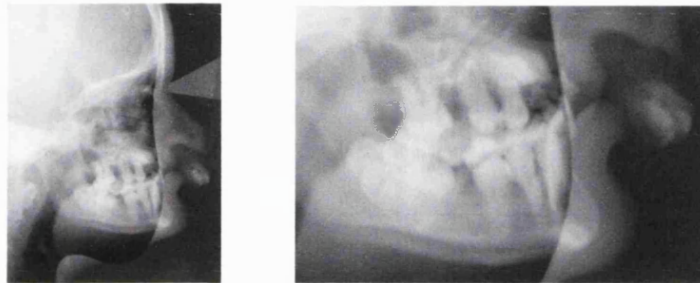
Fig 3.2.1 Lateral Skull Radiographs of an Unoperated subject

Fig. 3.2.2 Dental Study Models of an Unoperated subject

Fig. 3.2.3 Intra-Oral Photographs of an Unoperated subject
This subject had previously had a failed lip repair

Fig 3.3 A Pre and Post lip repair patient
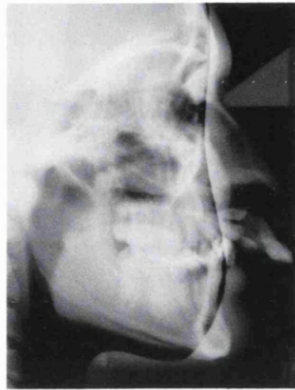
Fig 3.3.1 Unoperated Subject - Age 17   Fig 3.3.2 Post Lip Repair - Age 18
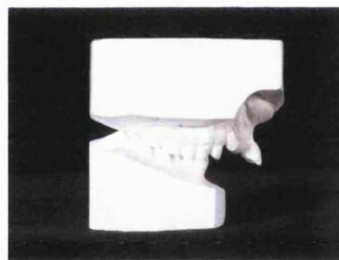
Fig 3.3.3 Unoperated Subject - Age 17   Fig 3.3.4 Post Lip Repair - Age 18
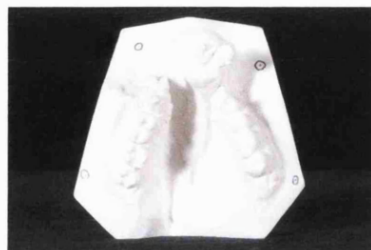
Fig 3.3.5 Unoperated Subject - Age 17   Fig 3.3.6 Post Lip Repair - Age 18

Fig. 3.4 Example of a patient who had palate surgery under 2.5 years

Fig 3.4.1 Unoperated subject - Age 1   Fig 3.4.2 Post Lip Repair - Age 2

Fig 3.4.3 Extra-Oral Photographs Post Palate Repair at Age 10, 13 & 17 years.

Fig 3.4.4 Lateral Skull Radiographs Post Palate Repair at Age 10, 13 & 17 years.

Fig 3.4.5 Dental Study Models Post Palate Repair at Age 10, 13 & 17 years.

Fig 3.5 Example of a patient who had palate surgery between 2.6 – 5 years

Fig 3.5.1 Extra-Oral Photographs Post Palate Repair at Age 9, 12 & 16 years.

Fig 3.5.2 Lateral Skull Radiographs Post Palate Repair at Age 9, 12 & 16 years.

Barium was injected into the nose during the x-ray procedure to emphasize the soft palate outline during functional speech to assess velopharyngeal closure.
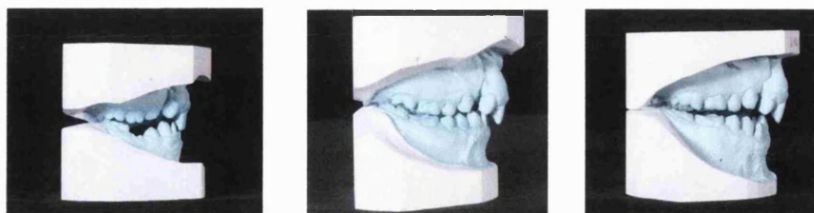
Fig 3.5.3 Dental Study Models Post Palate Repair at Age 9, 12 & 16 years.

Fig. 3.6 Example of a patient who had palate surgery between 5.1 – 10 years

Fig 3.6.1 Extra-Oral Photographs Post Palate Repair at Age 11 & 14 years.
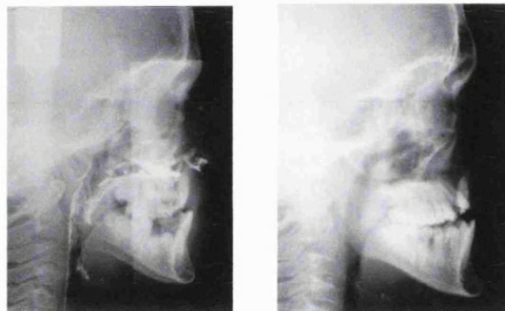
Fig 3.6.2 Lateral Skull Radiographs Post Palate Repair at Age 11 & 14 years.
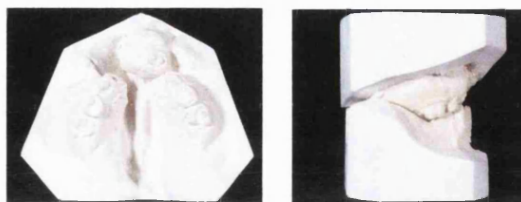
Fig 3.6.4 Dental Study Models Post Lip Repair - Age 6
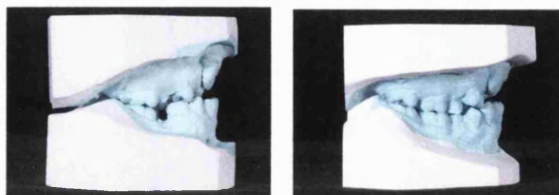
Fig 3.6.5 Dental Study Models Post Palate Repair at Age 11 & 14 years.

Fig. 3.7 Example of a patient who had palate surgery between 10.1 – 18 years

Fig 3.7.1 Extra-Oral Photographs Post Palate Repair at Age 13, 18 & 23 years.

Fig 3.7.2 Lateral Skull Radiographs Post Palate Repair at Age 13, 18 & 23 years.

Fig 3.7.3 Dental Study Models Post Palate Repair at Age 13, 18 & 23 years.

Fig. 3.8 Example of a patient after lip repair only over the age of 18.

Fig 3.8.1 Extra-Oral Photographs:
Unoperated at Age 25 years   After Lip Repair only at Age 28 years.
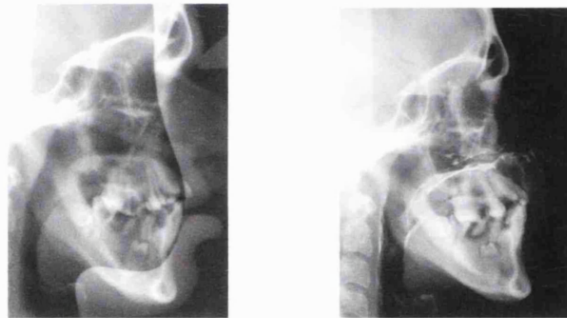
Fig 3.8.2 Lateral Skull Radiographs:
Unoperated at Age 25 years   After Lip Repair only at Age 28 years.
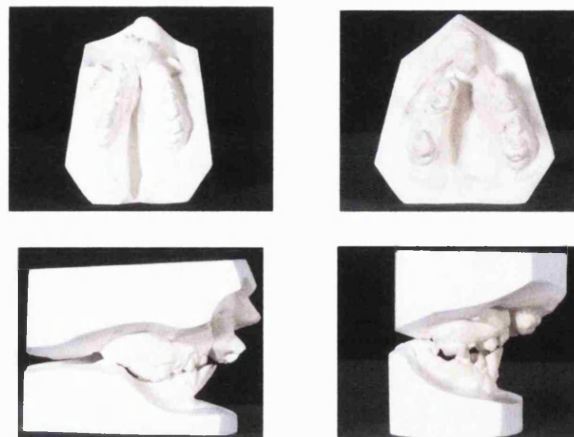
Fig 3.8.3 Dental Study Models:
Unoperated at Age 25 years   After Lip Repair only at Age 28 years.

Controls

The facial growth controls are 497 healthy Sri Lankan non-cleft subjects. These comprise 238 male and 259 female subjects aged between 6 and 30 years. Further discussion on the Control subjects is provided later in Chapter 4.

Records collected for study

Lateral skull radiographs of the 81 BCLP subjects comprise the material for the cephalometric analysis. Dental study models were available for arch relationship and morphology examination as a back up confirmation of the lateral skull position. A total of 191 lateral skull radiographs were taken at 6 years of age or older.

Radiographs

The lateral skull radiographs were taken in a cephalostat sited in a private x-ray room of the Central and Southern General Hospital in Galle. The cephalostat, which is used to position the head for the lateral skull radiographs, was consistently set to the protocol established in 1984, as described by Mars' (1993). The distance between the anode and x-ray plate on each visit is supervised to ensure the same magnification of the exposed x-ray:

> Great care was taken at each radiographic session to ensure that the anode to mid-sagittal distance was precisely 152.5cm (the Imperial measurement of five feet) and the mid-sagittal plane to the film distance

was 16 cm. The central ray was arranged at right angles to the sagittal plane. This was determined by an electric light source within the anode housing, casting a super-imposed shadow of both ear rods on a sheet of white paper, which was attached to the x-ray film cassette. These measures ensured reproducible lateral skull radiographs on all occasions with consistent magnification error. The patients were posed with the teeth lightly occluded in maximal intercuspation and the Frankfurt Plane parallel to the ground.

All radiographs were developed on the same day with the patient present; each radiograph was examined to ensure the correct exposure to ensure all landmarks were identifiable.

Preliminary validation technique

A 10% sample of healthy Sri Lankan control and unilateral cleft lip and palate subject x-rays (n=30) were hand traced twice to determine landmark recognition and accuracy (observers MM, EW). The study required a customisable computer programme allowing individual points to be digitised and measured reliably to cross-reference the data with previous work on the Sri Lankan Project. (Mars et al., 1990; Mars, 1993; Muthusamy, 1998; Arshad, 1998) Frequent modification of existing computer programmes to enable refinement of the digitisation was necessary.

Measurement of the 191 BCLP lateral skull radiographs and some control subjects was performed in four different cephalometric digitisation computer programmes. These were: Cogsoft, Opal, Viewbow 2.0 and Gela. Some were not flexible enough to modify the program to the facial growth measurements and angles required. Brief descriptions of the programmes are listed below:

Cogsoft is a cephalometric digitisation programme. Direct digitisation from the radiograph on a light box, to record points via a digi-pad, enables direct data input into the computer. It is a widely used MS-DOS based program but was difficult to understand and manipulate.

Opal is the updated Windows based version of Cogsoft which is easier to manipulate but has pre-set values to analyse the data, based on Caucasian normative data, which are unsuitable for this study. This programme has pre-set analysis menus and no self-defining program to be able to add extra points.

The Viewbox 2.0 programme enables direct digitisation from the cephalogram via a lightbox or enables on-screen digitisation of a scanned cephalogram. However the magnification of the images differed between the direct digitised x-ray and the on screen image magnification. The results were unreliable and found to be incompatible with our computer equipment.

Gela is a computer language of mathematical measurements between points. This enables the user to design those points to be digitised in the analysis and the exact angles, perpendicular or linear measurements to be recorded. A fully customised programme allows direct comparisons between this study and the other published papers on the Sri Lankan patients.

Gela was chosen as the programme method after exclusion of the other software for the reasons given above. A programme was written to incorporate all the points and angles required to observe the changing facial skeleton. The selected series (n=30) of x-rays were digitised to investigate the error agreement between the digitised readings on the Gela programme.

Prior to digitising the x-rays a template was fitted onto the digitiser light box so that each radiograph was placed in the same place every time to reduce error on repeated readings. (Sandler, 1988) (See Fig. 3.9)
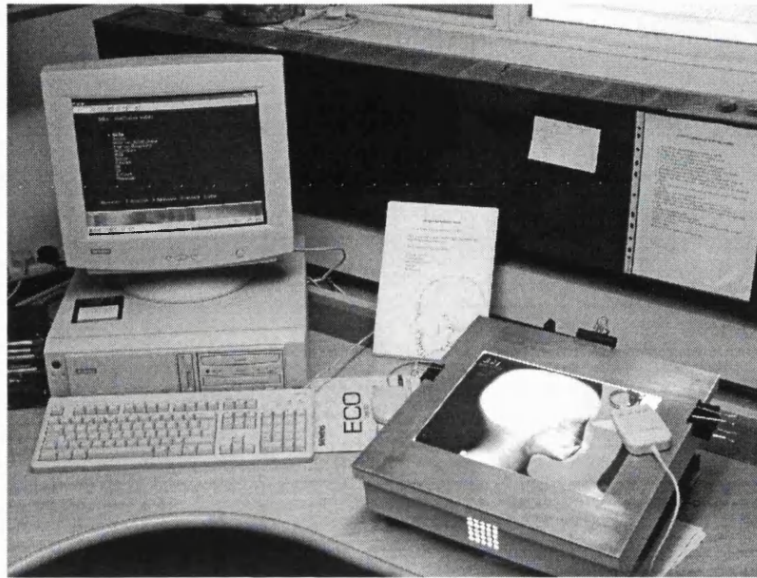
Fig. 3.9 Computer and Digitiser Workstation
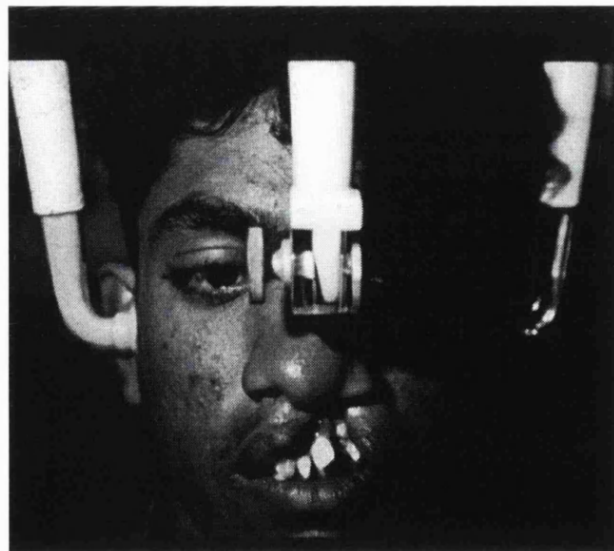
Fig. 3.10 Patient in Cephalostat

Radiographic Measurements

Fig. 3.11   Lateral Skull Digitisation Points
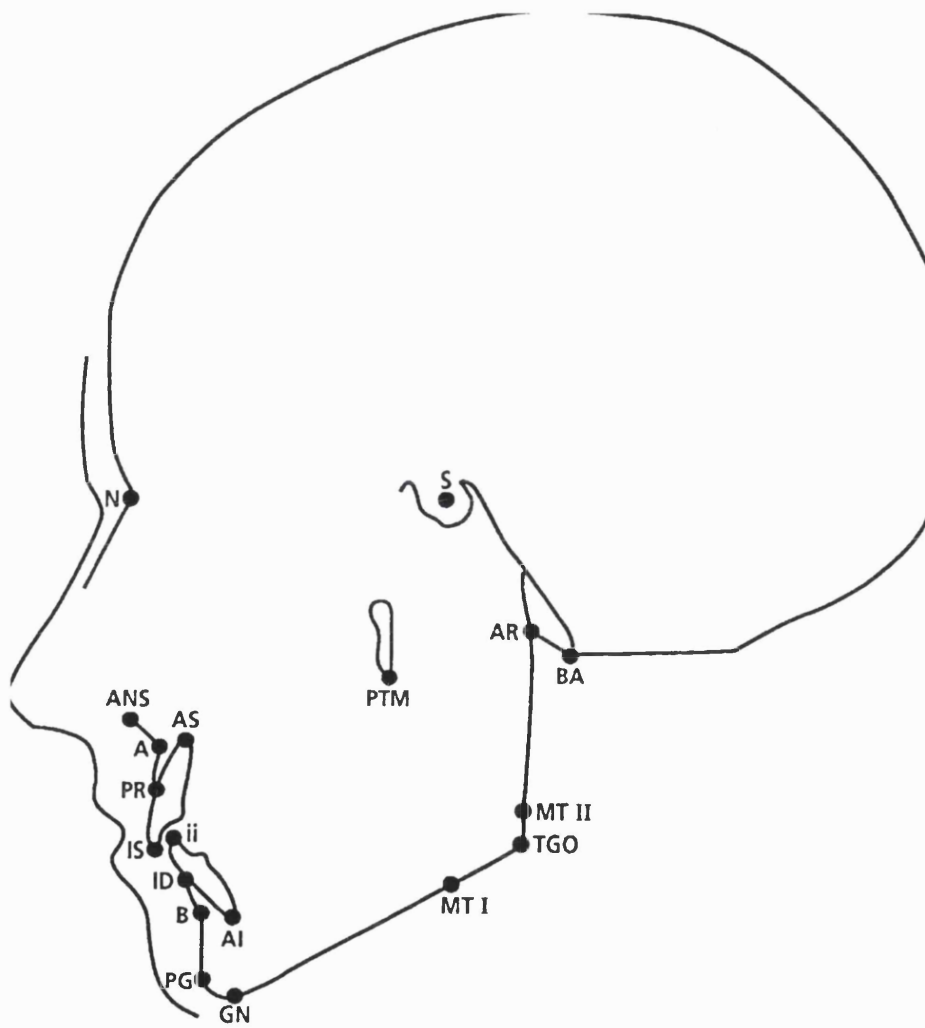
Reference Points

The 19 cephalometric landmarks, shown in Fig 3.11, listed below are based on the protocol designed for use in the European cleft lip and palate study. (Walther and Houston, 1994; Shaw et al., 2001b)

A   Subspinale. The deepest point on the anterior of the upper alveolar arch.

AI   Apex inferius. The apex of the root of the most prominent lower central incisor.

ANS   Spina nasalis anterior. The apex of the anterior nasal spine.

AR   Articulare. The point at the intersection between the contours of the mandibular ramus and occipital bone.

AS   Apex superius. The apex of the root of the most prominent upper central incisor.

B   Supramentale. The deepest point on the anterior contour of the lower alveolar process.

Ba   Basion. The most posterior-inferior point on the clivus bone.

GN   Gnathion. The most antero-inferior point on the mandibular symphysis furthest from Nasion.

ID Infradentale. The most antero-superior point on the mandibular alveolar process.

II Incision inferius. The midpoint of the incisal edge of the most prominent lower incisor.

IS Incision superius. The midpoint of the incisal edge of the most prominent upper incisor.

MT1 The point at which a tangent to the lower border of the mandible is made through Gnathion.

MT2 The point at which a tangent to the posterior border of the mandible is made through Articulare.

N Nasion. The most anterior point on the frontonasal suture.

PG Pogonion. The most anterior point on the mandibular symphysis.

PTM Pterygoid Maxillary Fissure. The most inferior posterior point on the body of the maxilla. (posterior nasal spine does not exist in many cleft cases and is almost impossible to find in others.)(Ross, 1970)

PR Prosthion. The most antero inferior point on the upper alveolar margin.

S Sella. The centre of the sella turcica.

TGO Gonion tangent point. Point of intersection between the mandibular line

and the ramus line.

Reference Measurement Notation

All reference measurements are either Angular or Linear measures.

Ba_N is a linear measure. The _ denotes the linear measurement between Basion

and Nasion. All linear measures were in units of millimetres.

SNA is an angular measure. This is the angle between Sella, Nasion and A point.

All angles were measured in degrees.

S_N_ANS is the perpendicular linear distance of ANS from the S_N line.

S_N/AS_IS is the intersection angles between two lines. This is the intersection

between the S_N line and the upper incisor line.

Reference Measurements

Measurement of Lateral Skull radiographs provides data on:

1. **Cranial Base**

   Ba_N   S_N   Ba_S   BaSN

2. **Maxillary Protrusion and relation to the Cranial Base**

   SNA   SNAS   SNIS   SNPR   SNANS   NSPTM   Ba_PTM   Ar_PTM

3. **Facial Depth and Maxillary Length**

   ANS_PTM   Ar_ANS   Ar_A

4. **Maxillary / Mandibular Protrusion**

   ANB   NAPg

5. **Mandibular Protrusion**

   SNII   SNID   SNB   SNPg

6. **Mandibular Dimensions**

   AR_TGO   TGO_Gn   ARTGOGn   Ar_Pg   Ar_B

7. **Facial Heights (Perpendicular distance)**

   S_N_ANS   TGO_Gn_ANS   PTM_ANS_Gn   N_S_PTM   N_S_TGO

   S_N_Gn

8. **Maxillary / Mandibular Plane and Mandibular Plane / Cranial Base Angles**

      Gn_MT1/ PTM_ANS Gn_MT1/ N_S

9. **Incisor Relationships**

      S_N/ AS_IS II_AI/ Gn_MT1 AS_IS/ II_AI

Some examples of the Reference Measurements can be seen in Fig. 3.1

The above measurements were calculated by the software programme and displayed on the computer screen. The same sequence of reference points was systematically followed for each radiograph.

Validation Techniques and Error Method

Preliminary validation of landmark identification and accuracy was performed initially on hand tracing x-rays by two observers on two occasions. (MM & EW) Overall agreement was set that each point should be within 2mm or 2 degrees between the two digitised readings and the two observers.

Once accuracy was determined the cephalograms were measured twice, with at least a week between measurements, to minimise familiarisation of the radiographs and digitisation points. Where the two readings differed by more

than 2mm or 2 degrees a third reading was taken. On 3 x-rays the landmarks were so unclear to both observers that the point was agreed to be missing or to mark the x-ray with a pinpoint.

Error of the Method

There are 3 main sources of error in cephalometric measurement. (Baumrind and Frantz, 1971a; Baumrind and Frantz, 1971b):

1. Error of Projection
2. Error of Landmark Identification
3. Error of Tracing or Measurement

1. Error of Projection

Errors result from a head film being a two-dimensional shadow of a three-dimensional object. Since all landmarks do not lie in the same sagittal plane some magnification errors and distortion can result. This is due to the fact that x-rays are produced from a small source and diverge, resulting in magnification. Angular measurements are considered to be more reliable than linear measurements because of this problem of magnification. In this study the cephalograms were taken using the same cephalostat; set up in the same way, ensuring the magnification was the same in all of the x-rays.

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2. Errors in Landmark Identification

Landmark identification errors are the major source of cephalometric error. A number of factors affect landmark identification: the quality of the radiograph, the precision of the landmark definition and the operator registration procedure.

a. Quality of the Radiograph

This type of error can be minimised by using radiographs of high quality. (Houston, 1983) All x-rays in this study (191 BCLP and 497 Control) were developed on the same day, with the patient present and examined to ensure the correct exposure and to ensure all landmarks were identifiable. If the radiographic landmarks were unidentifiable the radiograph was repeated. In 5 out of 689 the x-rays were repeated.

b. Precision of the landmark identification

Cephalometric landmark identification in the cleft lip and palate subject can be difficult. Some landmarks are harder to see in the cleft population than in others e.g. ANS. Houston (1983) recommended repeat digitisation as it reduces the risk of gross error due to incorrect

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landmark identification and reduces the size of random error. This was routinely done throughout this study.

c. Operator Registration procedure

Houston (1983) also noted that the operator's experience and working conditions affect the magnitude of the cephalometric error.

3. Errors of Tracing or Measurements

Direct digitisation into the computer reduces this type of error. Each radiograph was placed and held firmly into the digi-box template to ensure high accuracy and good reproducibility.

Forsyth compared the diagnostic quality of conventional radiographs with that of digital image counterparts. (Forsyth et al., 1996a; Forsyth et al., 1996b) They concluded that the digital image is unable to match the conventional radiograph in dynamic range and sensitivity to small changes. The random error associated with angular or linear measurements and landmark identification tends to be greater with digital images than with conventional radiographs.

Ross highlighted the error of variation in radiographic magnification, which could disguise a real difference or introduce a false one. (Ross, 1987a) In his study the cephalometric analysis was based on scanned images being fed into the computer

and on screen digitisation methods, which constituted another source of magnification and measurement error.

Intra-Operator Reliability

Houston (1983) recommended using the coefficient of reliability as the error measure, but commented that Dahlberg's estimations combine the systematic and random errors. Dahlberg's statistic uses the concept of error and its relationship to the measurement. (Dahlberg, 1940) Replicate measurements for each series are compared and the standard deviation of each paired measurement forms its own pair mean. However more recently Battagel reported on a comparative assessment of cephalometric errors. Her conclusions were to use Dahlberg's estimation and supplement this with the coefficient of reliability (Battagel, 1993). Errors between replicate measurements should be related to the variance of the landmark identification in the whole study, the error coefficient should ideally be less than 3%; a coefficient of greater than 10% would indicate the measurement was poor. Dahlberg's estimation was reported as the soundest method mathematically to evaluate measurement error. The coefficient of reliability provides sensitivity to sample composition and sample size. (Houston, 1983; Midtgard et al., 1974)

Statistical Notation

The error measure was calculated from the following formulae using the following:

Se = standard deviation of the differences of each replicate measurement from its

mean

n = number of radiographs

d = difference between the first and second readings.

Σ = sum of the differences

Dahlberg's estimate

$$Se = \sqrt{\frac{\Sigma d^2}{2n}}$$

Coefficient of Reliability

Coefficient of Reliability $\quad = 2\sqrt{\frac{\Sigma d^2}{n}}$

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Chapter 3

B) STATISTICAL METHODS

Normative data for the Sri Lankan population were used to adjust the facial growth measures of the BCLP subjects for age and sex. This was done calculating growth centile curves for each measure, based on the control data, which were then used to convert the BCLP measures to a standard deviation score adjusted for age and sex. A standard deviation score is the number of standard deviations that a value is above or below the mean.

Reference centile curves show the distribution of a measurement as it changes according to some covariate, e.g. age. (See Fig. 3.12.) The chart in Fig.3.12 shows an example of the distribution of growth measurements of one variable, SNA from birth to 30 years of age. Standard deviation scores (SDS) are used as an alternative to the traditional percentile curves of the population mean, where the 50th percentile represents the average value for age.

The LMS method summarises the reference data in terms of the median (M), coefficient of variation (S), and the skewness (L), expressed as a Box-Cox power,

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as they change with age. The three quantities plotted against age are called the L curve, M curve and S curve respectively. The three curves are fitted as cubic splines by non-linear regression and the extent of smoothing required is expressed in terms of smoothing parameters or equivalent degrees of freedom (e.d.f.). The LMS program fits smooth centile curves to reference data using the LMS method. LMS Light Program version 1.16 was used. (Cole and Green, 1992; Cole et al., 1998; Freeman et al., 1995)
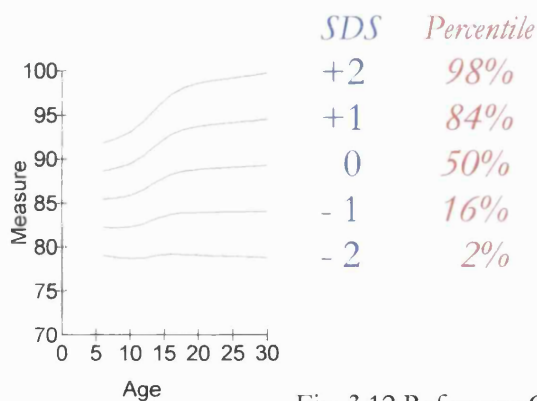
Fig. 3.12 Reference Centiles for SNA

The process involves five stages: Data Entry, Model Fitting, Graphical Display, Model Checking and Model Saving.

Data Entry

The data are entered into the LMS program from a tab delimited text file (e.g. Excel). The subjects were separated into male and female spreadsheets and analysed separately. The data for the Control Male SNA variable is shown in Fig. 3.13.

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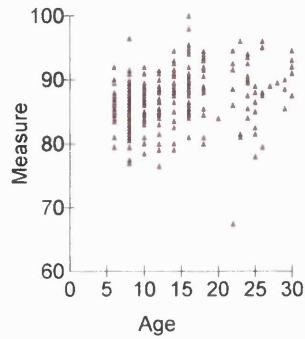
Fig. 3.13 Control Male SNA Data Plot

Model Fitting

The number of centiles can be specified and the standard deviation (SD) or spacing between the centiles can be selected. In this study each centile was calculated to represent 1 standard deviation from the control population mean and 5 growth centiles were used. The 5 growth centiles were used to represent 95% of the control population distribution. The middle growth centile represents the control population mean and the remaining centiles represent the 2 standard deviations above and below the population mean shown in Fig. 3.14.
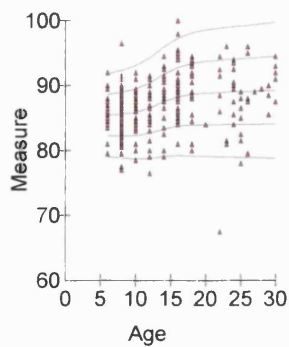
Fig. 3.14 Control Male SNA Data Plot & centiles

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Graphical Display

The LMS Light program has five graphical displays; Data plot, L curve, M curve, S curve and centiles. The data graph is drawn when the data are read into the program. The L curve, M curve and S curve are drawn with the selected centiles when the model is fitted. The curves are adjusted for the equivalent degrees of freedom (edf) required for each measure. In this study the L curve (skewness) was set at 1 edf, corresponding to a normal distribution at all ages. The M curve (median) was set at 3 edf, allowing for a curvilinear age trend over time. The S curve (coefficient of variation) was set at 2 edf, allowing for a linear age trend. From these values by age corresponding to 0, ± 1 & ± 2 standard deviation scores (SDS) can be calculated. An example of this is shown in Figs. 3.12.

Model Saving

The models can be saved as an LMS file. Values for LMS curves and the required centiles were saved in text form, to be exported into Excel.

Once the centiles had been calculated for all male and female 37 cephalometric values the centiles and L, M, S curve values tabulated by age (1 year intervals) were exported into Excel. Once in Excel names and definitions of the measurements were entered as a reference to the spreadsheet. This enables functions to be performed within the spreadsheet. The SDS function converts a

variable measurement (e.g. **SNA, Ba_N**) to a standard deviation score adjusted

for age and sex against the control population.

Chapter 4

THE CONTROL POPULATION.

For the purpose of clarity, a separate chapter dealing with the Control subjects is presented. This chapter is hybrid in form presenting the Control Subjects and Methods, Results and some discussion of those results. Further, the statistical techniques by which the BCLP subjects are compared to the Control population, using standard deviation scores, are presented.

In this study a unique method of analysing and presenting somatic growth measures has been adapted to present healthy non-cleft facial growth and height parameters for the Sri Lankan population. It is imperative to be able to analyse the relationship between the non-cleft and cleft growth features. This chapter presents the selection process of the control subjects and a description of control facial growth parameters used in this study. A separate group of control subjects is examined for height.

Control Subjects and Methods

Initially in 1986 the medical students in Galle were regarded as fit and healthy Sri Lankans, aged between 20 and 30 years, they formed the first control subjects and gave consent for x-rays to be taken, though no formal ethical approval had been sought at that time, for them (or any of the patients under treatment). This

however, may be biased, as most medical students would be from Sri Lanka's higher socio-economic classes. Subsequently, local paediatricians devised a list of schools and factories that provided an equal distribution of rural and urban populations. The schools and factories provided data on subjects aged between 6 and 18 years. Further data collection in Sri Lanka is used to collate more control data up to the age of 30 years. The control records collected were lateral skull and hand radiographs, height, weight and somatic growth measures together with a general questionnaire.

In this thesis two separate control studies were used to compare the BCLP sample to the non-cleft Sri Lankan population; one to study facial growth outcomes and the other to compare somatic growth measures.

The facial growth control population comprised every control subject who had had a lateral skull radiograph taken. This section of the control population incorporated 497 subjects, comprised of 238 males and 259 females. The age range of the facial growth controls are shown in Fig. 4.1. (Page 124) A typical lateral skull cephalogram of a typical non-cleft Sri Lankan control subject is shown in Fig. 4.2 (Page 125)

Somatic growth measures were available on 2872 control subjects, these subjects provided data on height, weight, and other somatic growth measures, none of these subjects had had a lateral skull radiograph taken. These records were used to assess the heights of the BCLP sample by means of a standard deviation score

to the control population. Details of the facial growth and somatic growth control groups are shown in Fig. 4.1. Correlation between the timing of somatic growth and facial growth has long been debated in the literature. A separate examination into the relationship of facial growth and somatic growth was undertaken. An association between small linear facial growth measures and corresponding short stature may highlight an intrinsically short BCLP subject.

Facial Growth Study	Male	Female	Total
	238	259	497
Age Range	6 – 55 years		

Height Study	Male	Female	Total
	1423	1449	2872
Age Range	Birth – 18 years		

Fig. 4.1 The Control Population
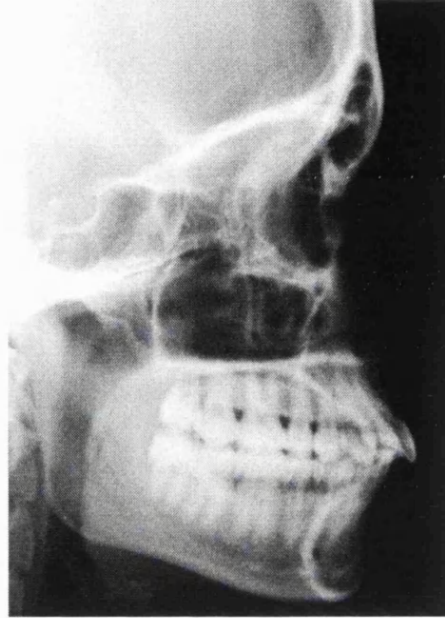
Fig. 4.2 Lateral skull cephalogram of a typical non-cleft Sri Lankan subject.

Control height values were entered into Excel and converted into standard deviation scores (SDS) in the LMS program, by the same process that was used as in Chapter 3 B) Statistical methods. In Chapter 3 the facial growth control methodology is described in detail (Pages 117-121).

Somatic growth measures on 1423 males and 1449 females form the control height data, the dataplots and centiles are shown in Figs. 4.3 to 4.6. The control height data includes subjects from birth to age 18 years. The height measures for all BCLP subjects were then converted into SDS against an age, sex matched control subject. All height data for the BCLP sample study subjects of older than 18 years are frozen as if at the value of an 18-year control subject to enable a SDS to be calculated.

Control Height Study Results

Female Control Heights
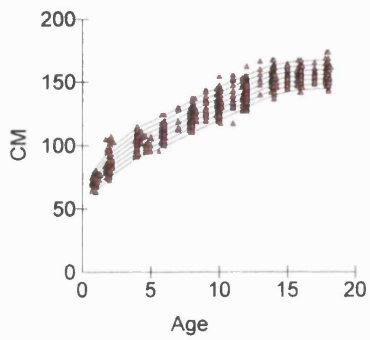
Fig. 4.3 Data Plot & Centiles
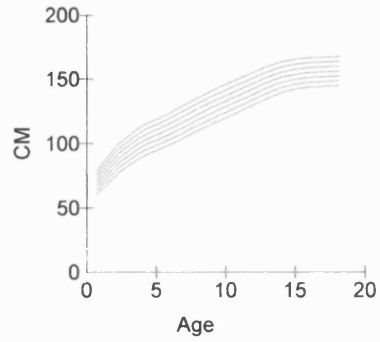
Fig. 4.4 Female Height Centiles

Male Control Heights
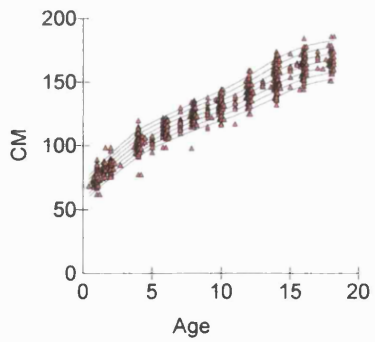
Fig. 4.5 Data Plot & Centiles
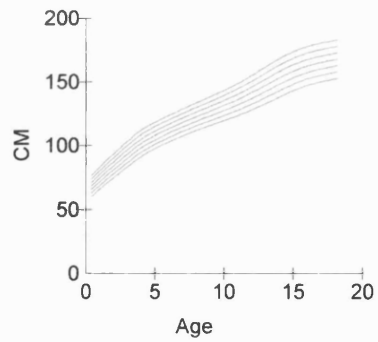
Fig. 4.6 Male Height Centiles

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Fig. 4.7 Female Height SDS

BCLP Female Heights
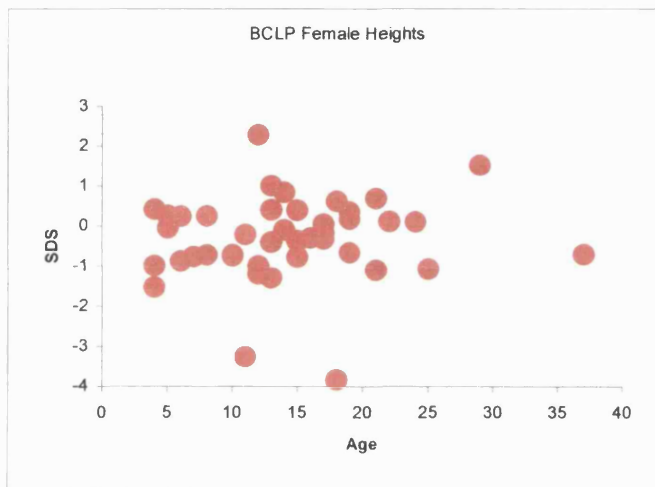
Fig. 4.8 Male Height SDS

BCLP Male Heights
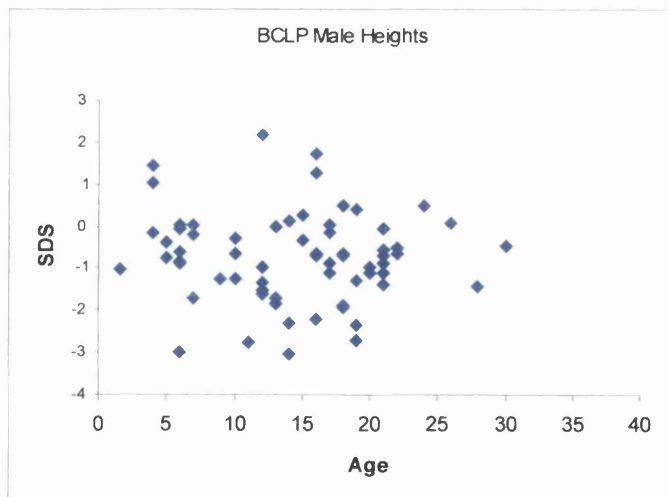
Fig. 4.9 Control and BCLP Heights
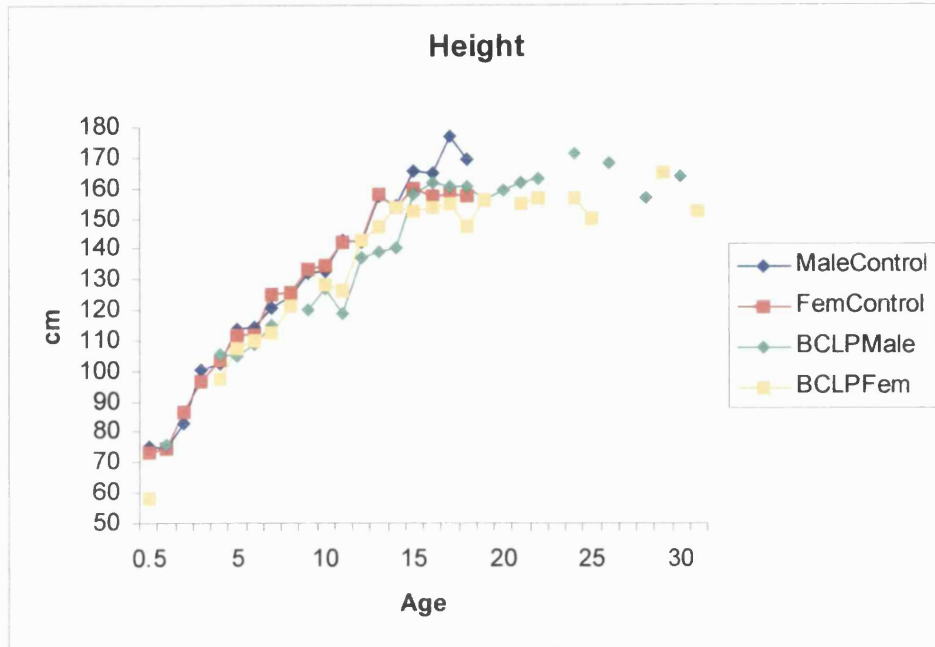
Preliminary investigation into the timing of somatic growth and facial growth has not shown any correlation in this study. Analysis of the BCLP subjects SDS was found to be within the 95% confidence interval for the control population distribution.

Control Population Discussion

The BCLP sample tended to be slightly shorter than the population mean but within two standard deviations from the population mean, representing the 95% confidence interval for the control population distribution. This preliminary investigation was performed to ascertain a correlation, if any, between somatic

and facial growth attributes. No significant differences in Height were found between the BCLP cohort and the Control population in this study.

Limitations of the non-cleft healthy Sri Lankan population (Controls)

Ethical approval was obtained for all the non-treatment associated growth records required for the data collection (see page 89). One lateral skull cephalogram and a hand radiograph were taken on 497 facial growth control subjects. The hand radiographs are collected to measure bone maturity, to assess the stages of Sri Lankan pubertal process, which form part of a separate study. The 497 controls used in the facial growth study provided the facial growth parameters to establish the facial growth centiles.

The control subjects in the height data analysis incorporated 2872 control subjects. The disparity in numbers between the two groups of control subjects reflects the simplicity in collecting somatic measures, in comparison to the logistical difficulties of collecting radiographic records. This topic is further discussed in the limitations of the study design in Chapter 5) Discussion and Conclusions.

Further records are required to be able to accurately predict the somatic and skeletal pre and post pubertal growth curves for the Sri Lankan population. Ongoing data collection of general somatic records, heights and weights up to the age of 30 years are still being collected in Sri Lanka and form part of a separate study.

Statistical Techniques

An overview of how the results chapter will be presented and the statistical techniques discussed with specimen charts is now provided. Results of the main study in Chapter 5) will be presented in separate sections:

The Unoperated Subject

This section deals with the totally Unoperated subjects. A cross-sectional analysis examines subjects who have had no surgery whatsoever undertaken to the lip or palate.

The PostLip Repair

This section deals with the post lip repair subjects. A cross-sectional analysis examines subjects who have had surgery to repair the cleft lip only. No surgery to the palate has been undertaken.

The PostPal Repair

This section deals with the post palate repair subjects. A longitudinal analysis examines subjects who have had surgery to repair the lip and palate. Five groups encompass a variety of palatoplasty timing, subdivided by the age at palate repair.

Facial growth outcomes beyond 18 years of age

This section presents the cross-sectional analysis on all subject groupings measured over 18 years of age.

Specimen Charts – an explanation.

Cross-sectional analysis of the UNOP and POSTLIP groups.

All of the cross-sectional results will be presented as Scatter plots. Each individual subject is represented as a different icon. Comparison will be made with the controls by means of using the age and sex matched Standard Deviation Scores (SDS). The growth for the control population mean on a SDS is plotted in Fig. 4.10. A subject growing at the same rate and score for the population mean is expressed as a straight line at 0. In Figure 4.11, the control population distribution is shown; $\pm$ 2 standard deviations from the control population mean. This represents where 95% of the control population would lie. Any SDS within these lines is regarded as within the normal population distribution for age.
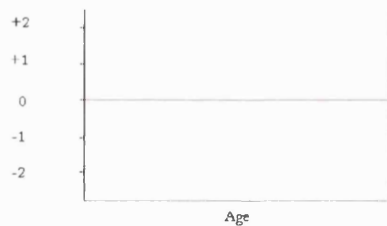
Fig.4.10 Control Mean growth score   Fig. 4.11 Control Distribution
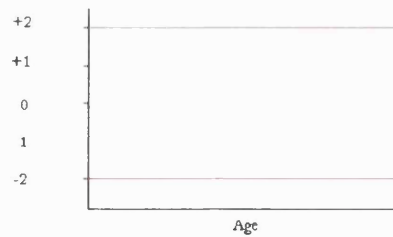
(95% Confidence interval)

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A single variable, SNA, has been selected to demonstrate the cross-sectional specimen charts are shown in Fig. 4.12 & 4.13. For each variable the cross-sectional data for the Unoperated and PostLip repair subjects will be displayed as Scatter plots. For each variable the SDS will be plotted against Age. The SDS for each BCLP subject has been calculated to be age and sex matched with the control population. Each subject is identified by a different symbol. The cross-sectional analysis allows direct comparison between the Unoperated and PostLip subgroups. All the cross-sectional analysis variables in Chapter 5) will be presented in this manner.

All subjects in the Cross-sectional data have been converted from the actual angular or linear measure into a SDS by means of the LMS program. No supplementary statistical analysis was performed on the cross-sectional data as most subjects are incorporated within the longitudinal data analysis of the main study where multiple linear regression is used to test statistical significance.

Description of the Cross-sectional Specimen Chart
In Fig 4.12 the data spread is largely within the 95% confidence interval for the Control population (+2 to –2). The effect of the lip repair can be seen to lower the SDS in the PostLip group, more low SDS values below the population mean value of 0 are seen in the post lip repair scatterplot, in Fig 4.13.

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Fig. 4.12 Cross-sectional Unoperated Specimen Chart
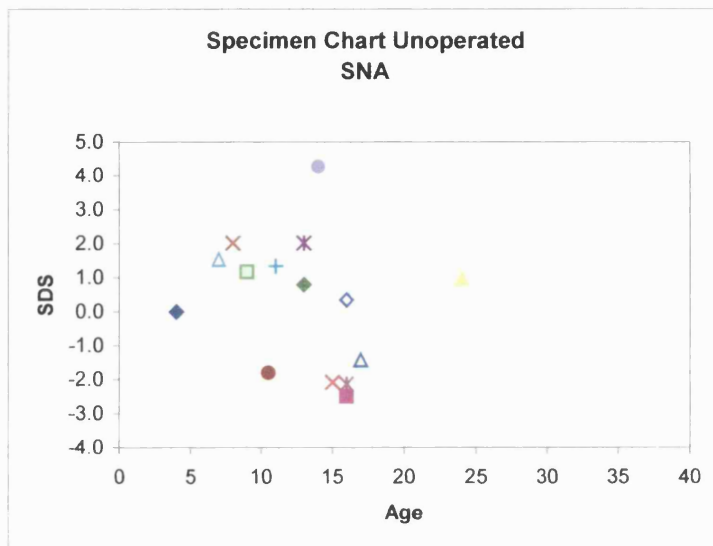
Fig. 4.13 Cross-sectional PostLip Specimen Chart
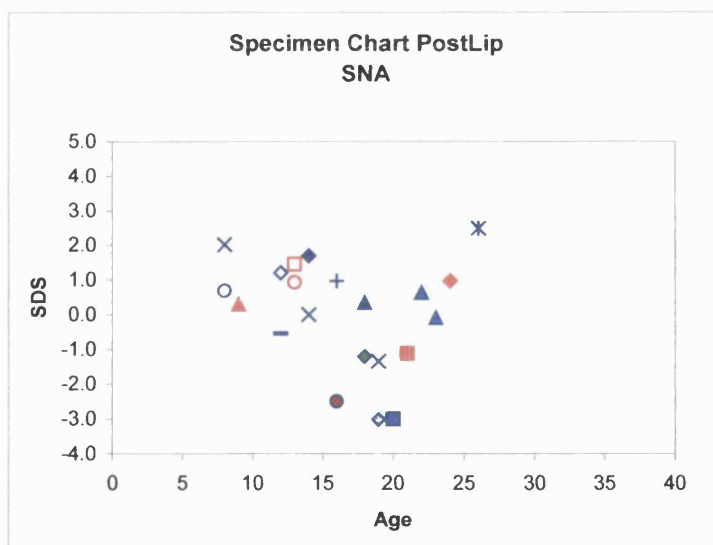
Specimen Charts – an explanation.

Longitudinal analysis of post palatal groups.

The Longitudinal analysis is performed on standard deviation scores (SDS) of all postoperative BCLP subjects. All subjects in the PostPal groups have had lip and palate repair. Each BCLP subject SDS for each facial growth variable is plotted longitudinally. A different coloured icon represents an individual subject and each data point is linked to show consequent facial growth. Individual subjects have been coded according to their surgical intervention. An Unoperated subject is represented as a triangle. A PostLip subject is represented as a circle or star. A PostPal subject is represented as a square. No distinction is made between the outlined or coloured shapes, the coding is solely for individual subject identification and timing of surgical intervention.

The data is subdivided into groups according to the age at which palatal repair occurred. Five groups encompass a variety of palatoplasty timing as described in Chapter 3 A) Subjects and Methods (Page 91). Each BCLP subject SDS for each facial growth variable was plotted longitudinally and subdivided into the 5 PostPal groups, according to the age at which palatal repair occurred.

Standard deviation scores are age and sex matched, a control subject with mean rates of growth would present with a SDS of 0 at all ages. The control population distribution (95% confidence interval) is represented within the 2 standard deviations above and below the population mean 0 SDS. Therefore a SDS within + 2 and − 2 is within the 95% confidence interval of the control distribution. An indepth description of this technique is shown in Chapter 3 B) Statistical Methods (Page 117) and earlier in this chapter (Page 132).

The Research Questions

Three research questions were posed:

1. How do the subjects compare to the Controls?

2. What happens with growth? The growth trend over time.

3. What is the effect of the age of operation?

These questions can be quantified:

1. The overall mean variable value.

2. What happens with growth - the slope of the regression line?

3. What is the effect of the age at operation on the variable value - does the slope change according to the age at palate repair?

Qualitative Study

A qualitative overview on the initial presentation of the results was undertaken to observe the general growth characteristics. Subjective interpretation of the graphs was carried out to highlight any apparent growth trends prior to the statistical analysis. Multiple linear regression was used later to support these findings and to test for more subtle growth differences.

A simple subjective rating scale was designed:

Very Low	Low	Same	High	Very High
--	-	0	+	+ +

A Control subject with mean rates of growth would present with a SDS of 0 at all ages. To rate the qualitative analysis, if the BCLP SDS was lower than the Control mean, 0 SDS; a 'Low' rating score would be rated, as a - . Equally a SDS lower than – 2 SDS, would score a - - and if the SDS were higher than 0 SDS then a + or + + would be scored.

An illustration of the qualitative approach is shown below, one variable has been selected, Ar_Pg. The qualitative analysis is based on the longitudinal graphs for Ar_Pg, shown in Fig.4.14 (Page 141 -143).

Table 4.1 Qualitative Analysis Specimen Chart

Question	1	2	3
Facial Growth Measurement			
Ar_Pg	+	+ +	-

Description of the Qualitative Specimen Chart

In the specimen chart the variable Ar_Pg showed:

1. Overall a high mean value.

2. Very steep rise with age.

3. Reduction in rate of rise with age at operation.

An explanation of the Qualitative Specimen Chart

1. In Fig.4.14 the BCLP subjects presented with overall a higher SDS in relation to the Controls. The overall mandibular length was longer in the BCLP subjects when compared to the Control population.

2. Subsequent growth was shown to be at a much faster growth rate than the Controls.

3. The final question examined the rate of growth within the PostPal groups. The growth coefficient decreased the later the palatal surgery was performed i.e. the older the subject was at palate surgery, the less growth effect observed, due to the majority of facial growth having occurred prior to palatal surgery.

A full table of the qualitative result presentation, for all variables, is shown in the Chapter 5) Results.

The Qualitative analysis was the precursor of the Quantitative statistical multiple linear regression. This provides the means for comparison between the timing effect of surgery, the effects on facial growth and the effect of the age at surgical intervention. The multiple regression model estimates a separate intercept for

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each subject, plus a linear trend for age at x-ray, plus a linear trend for age at operation. In addition, the model fits the interaction of age at x-ray with age at operation. Together the fitted coefficients provide tests for each of the three research questions Datadesk version 6.1.1 (Data Description, Ithaca NY, USA) was used for the analysis.

Description of the Quantitative Specimen Chart

The same criteria and questions were addressed by the longitudinal quantitative analysis. However rather than a value judgement, multiple linear regression was used to test statistical significance.

The same three questions were asked of each variable

1. The overall mean variable SDS value.

2. What happens with growth - the slope of the regression line, for the age at x-ray?

3. What is the effect of the age at operation on the variable value - does the slope change according to the age at palate repair? This is the slope for the interaction of the age at x-ray with the age at operation.

As before a specimen chart outlining the quantitative longitudinal data analysis is shown in Fig.4.14 (Pages 141 -143). A single variable, Ar_Pg, has been selected to demonstrate the longitudinal specimen charts.

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The statistical analysis is shown in the results table. Three types of statistics were used to interpret the results.

1. The regression coefficient (Coeff.) describes the slope of the line.

2. The t ratio is the ratio of the regression coefficient to the standard error: *t ratio = slope /standard error.*

3. The P value is the level of significance.

The Statistical analysis for these results show:

1. A high overall mean value; + 0.69 SDS, which was highly significant in comparison to the Control population.

2. Steep rise with age; + 0.38 SDS rise per year, which was highly significant in comparison to the Control population.

3. Reduction in rate of rise with age at operation, which was highly significant. Illustrating that the older the subject is at palatal surgery for this variable the flatter the regression line becomes. An interaction of - 0.02 SDS change per year in the slope. For example a change of - 0.02 SDS over 20 years, – 0.02 x 20 = - 4. A slope of + 4 in childhood becomes 0, i.e. flat as an adult.

The statistics in the quantitative analysis supports the value judgement rating scale of the qualitative analysis findings.

Fig. 4.14 Quantitative Analysis Specimen Charts for Ar_Pg
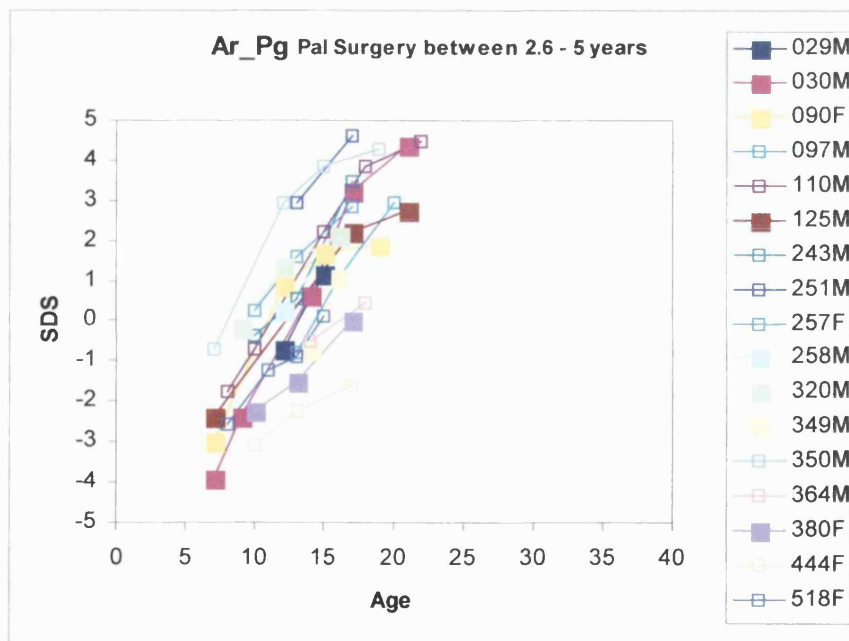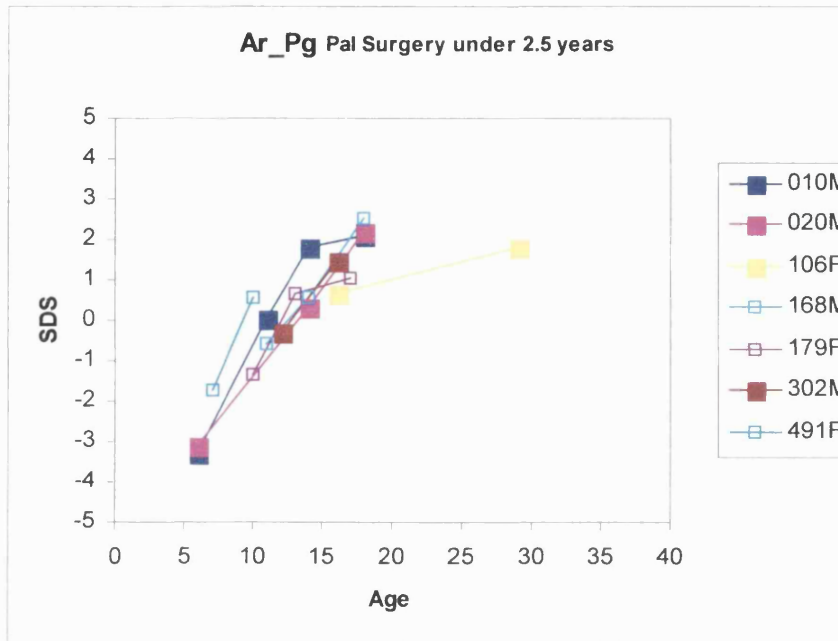
Ar_Pg Pal Surgery under 2.5 years

Ar_Pg Pal Surgery between 2.6 - 5 years

Fig. 4.14 Quantitative Analysis Specimen Charts for Ar_Pg contd.

Ar_Pg Pal Surgery between 5.1 - 10 years

Ar_Pg Pal Surgery between 10.1 - 18 years

Fig. 4.14 Quantitative Analysis Specimen Charts for Ar_Pg contd.

Ar_Pg Pal Surgery over 18.1 years

Legend:
- 042M
- 076M
- 132M
- 178F
- 371M
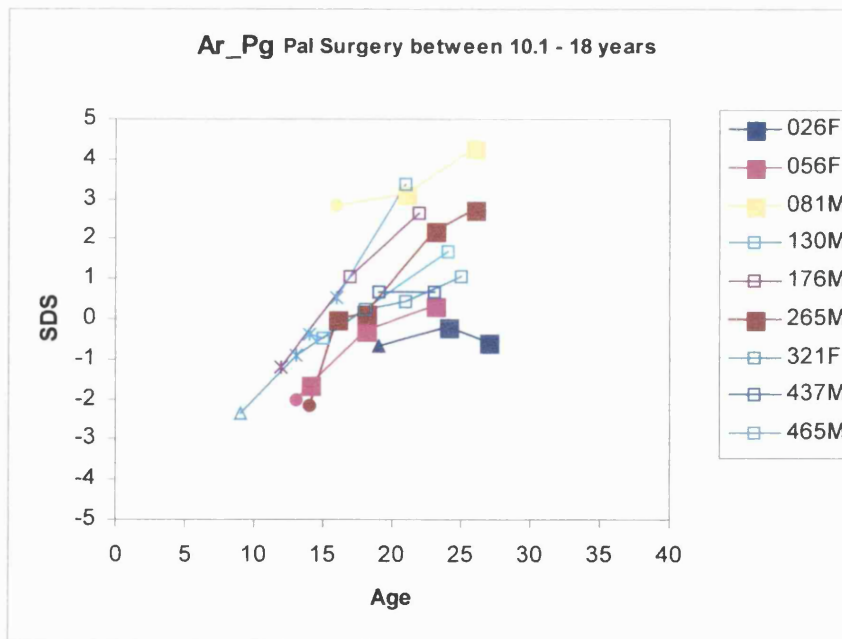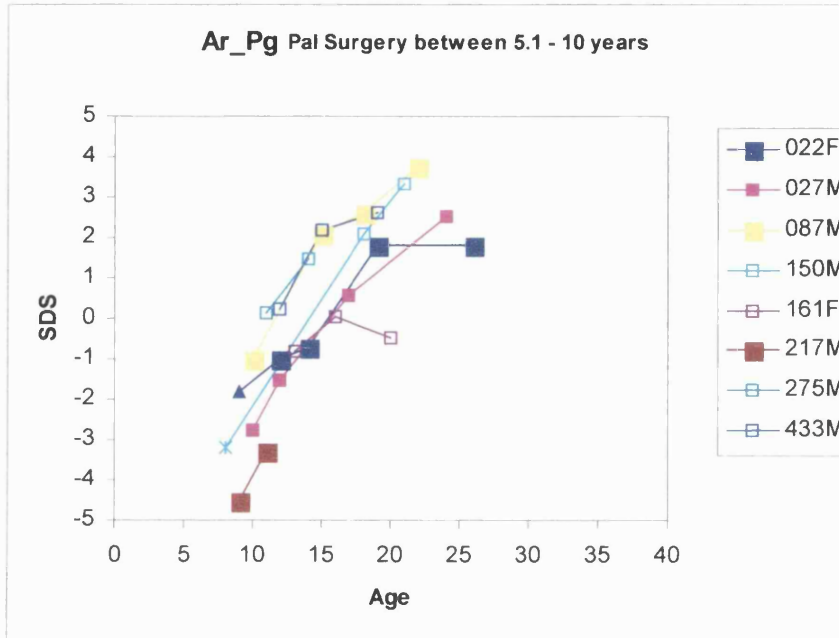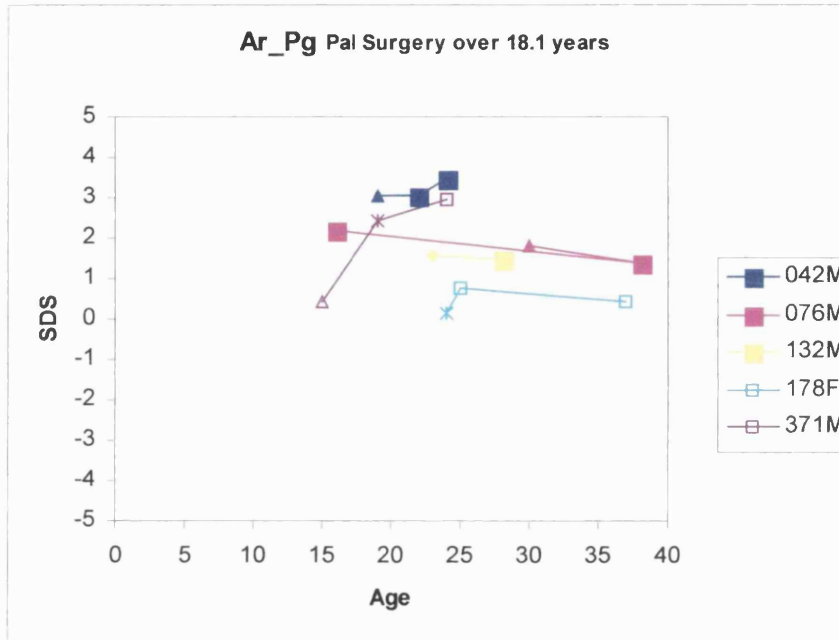
Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.69	3.95	**0.0001**
2	0.38	19.95	**0.0001**
3	- 0.02	- 4.45	**0.0001**

Chapter 5

RESULTS

The results are presented under the following headings:

A) Results of the Repeatability Study

B) Results of the Qualitative Study

C) The Unoperated Subject

This section deals with the totally unoperated subjects. A cross-sectional analysis examines subjects who have had no surgery whatsoever undertaken to the lip or palate.

D) The PostLip Repair

This section deals with the post lip repair subjects. A cross-sectional analysis examines subjects who have had surgery to repair the cleft lip only. No surgery to the palate has been undertaken.

E) The PostPal Repair

This section deals with the post palate repair subjects. A longitudinal analysis examines subjects who have had surgery to repair the lip and palate. Five groups encompass a variety of palatoplasty timing, subdivided by the age at palate repair.

F) Facial growth outcomes beyond 18 years of age

This section presents the Cross-sectional analysis on all subject groupings measured over 18 years of age.

A) Results of the Repeatability Study

The method error and repeatability study were calculated according to Dahlberg's estimation and the coefficient of reliability. (Battagel, 1993)

The results of the repeatability study showed Dahlberg's Estimation to be $0.63°$ for angular measures and to be 0.51mm for linear measures. In terms of the coefficient of reliability this study results were within 1.77% for angular measures and within 1.43% for linear measures.

B) Results of the Qualitative Study

A description of the qualitative analysis and a specimen chart is provided in Chapter 4) Statistical Methods (Page 137).

Table 5.1 Qualitative Scoping Exercise

	1	2	3
Cranial Base			
Ba_N	--	++	-
S_N	-	+	-
Ba_S	--	++	-
BaSN	0	+	-
Maxillary Protrusion & Relation to Cranial Base			
SNA	0	-	--
SNAS	0	-	-
SNIS	-	-	-
SNPr	-	-	-
SNAns	---	++	-
NSPtm	0	+	-
Ba_Ptm	--	++	-
Ar_Ptm	0	+	-
Facial Depth & Maxillary Length			
Ans_Ptm	0	-	+
Ar_Ans	0	-	+
Ar_A	0	-	+
Maxillary / Mandibular Length			
NaPg	---	-	0
Mandibular Protrusion			
SNII	-	-	+
SNID	-	+	-
SNB	-	+	-
SNPg	-	+	-
Mandibular Dimensions			
Ar_TGO	-	++	-
TGO_Gn	-	++	-
ArTGOGn	0	-	+
Ar_Pg	+	++	-
Ar_B	+	++	-
Facial Heights (Perpendicular distance)			
S_N_Ans	0	++	-
TGO_Gn_Ans	+	+	-
Ptm_Ans_Gn	+	+	0
N_S_Ptm	-	++	-
N_S_TGO	0	++	-
S_N_Gn	+	++	-
Maxillary / Mandibular Plane & Mandibular Plane / Cranial Base Relations			
Gn_MT1 / Ptm_Ans	0	-	+
Gn_MT1 / N_S	0	-	+
Incisor Relations			
S_N / AS_IS	--	+	-
II_AI / Gn_MT1	--	-	-
AS_IS / II_AI	++	-	+

C) The Unoperated Subject

This section deals with the totally Unoperated subjects. Cross-sectional analysis examines individual subjects, at one point in time, who have had no surgery whatsoever undertaken to the lip or palate.

The results for both the Cross-sectional and Longitudinal analysis will be presented under the facial growth and morphological headings:

1. Cranial Base

2. Maxillary Protrusion and relation to the Cranial Base

3. Facial Depth and Maxillary Length

4. Maxillary / Mandibular Protrusion

5. Mandibular Protrusion

6. Mandibular Dimensions

7. Facial Heights (Perpendicular distance)

8. Maxillary / Mandibular Plane and Mandibular Plane / Cranial Base Angles

9. Incisor Relationships

Some examples of the Reference Measurements are shown in Fig. 3.1 (Page 93).

Specimen charts for the cross-sectional and longitudinal data analysis are discussed in Chapter 4 (Pages 132 - 143).

Fig.5.1.1 Cross-sectional Unoperated Ba_N - Cranial Base
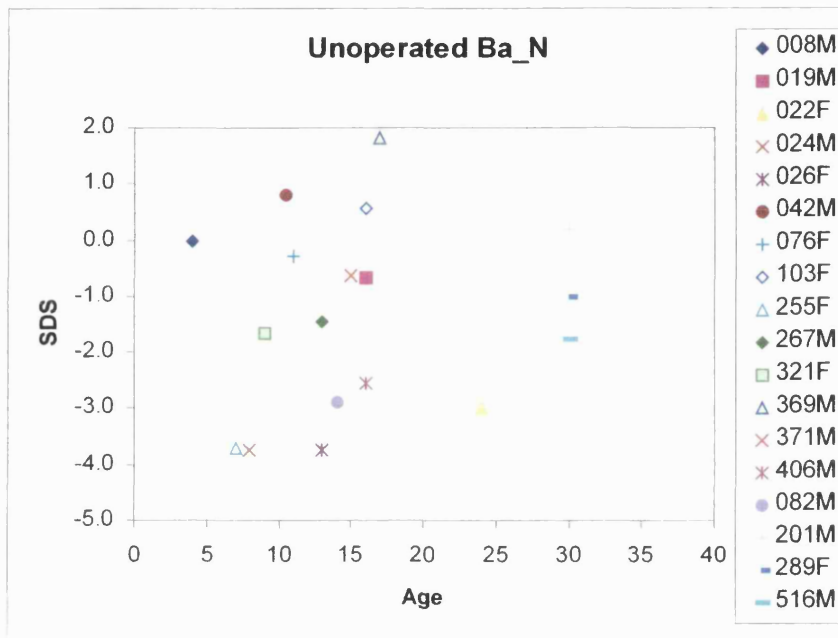
Fig. 5.1.2 Cross-sectional Unoperated SNA - Maxillary Protrusion
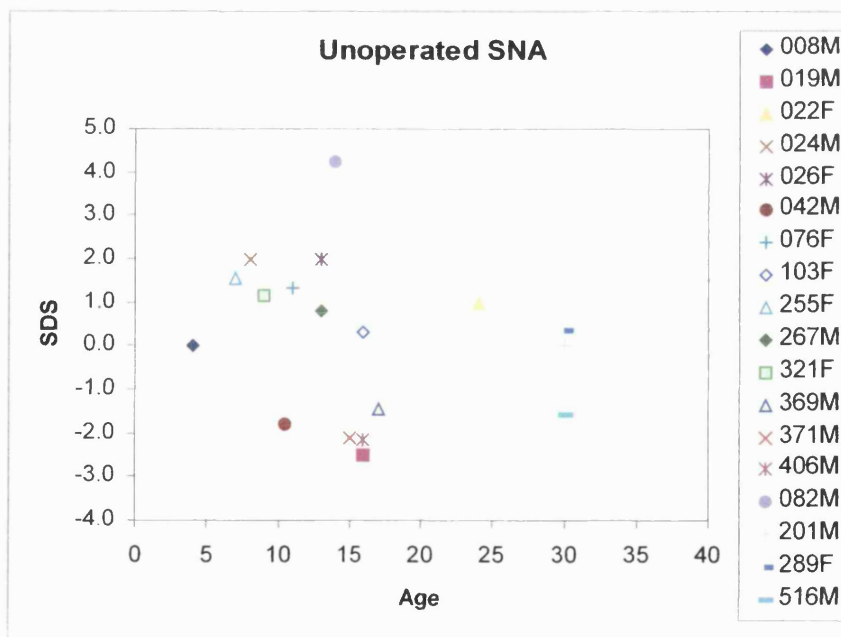
Fig. 5.1.3 Cross-sectional Unoperated SNAns - Maxillary Protrusion
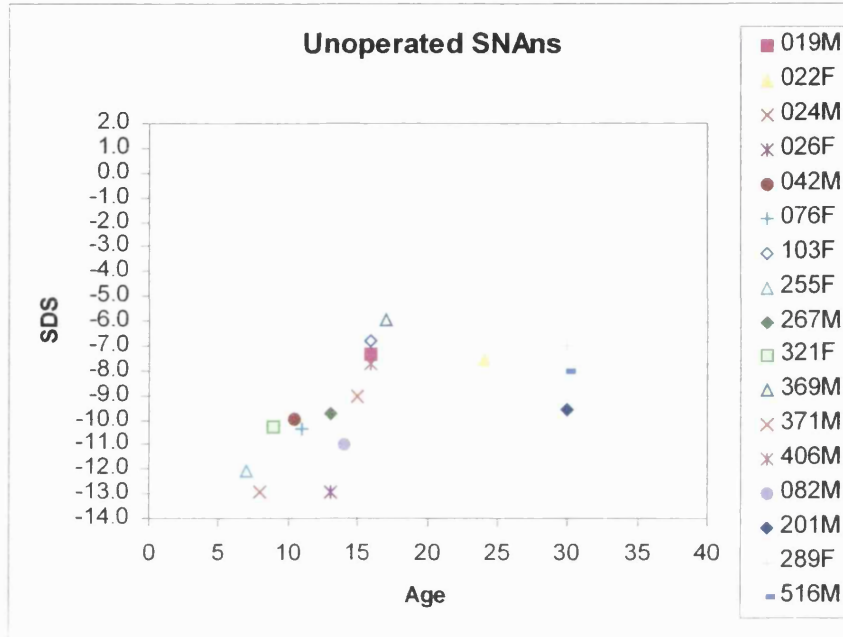
Fig. 5.1.4 Cross-sectional Unoperated NSPtm - Maxillary Protrusion
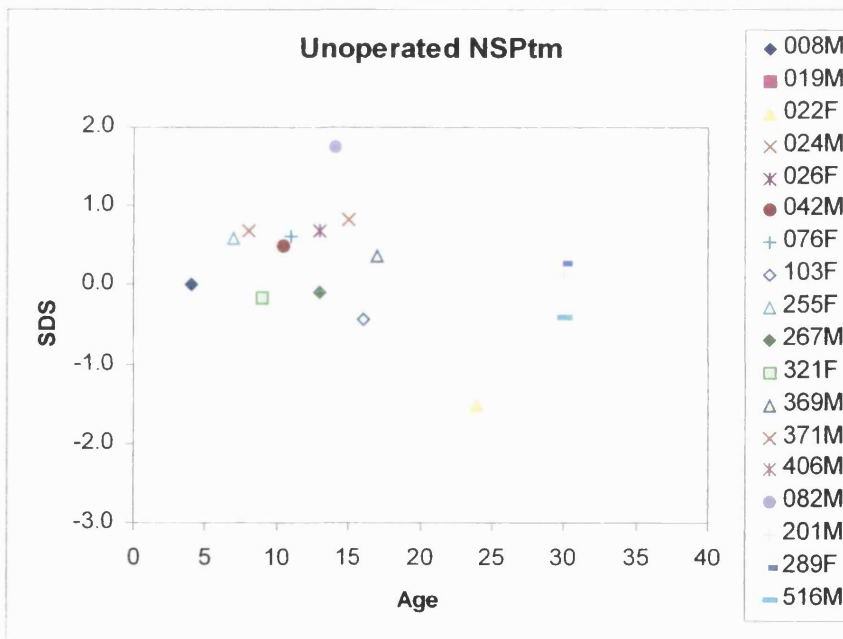
Fig. 5.1.5 Cross-sectional Unoperated Ba_Ptm - Maxillary Protrusion
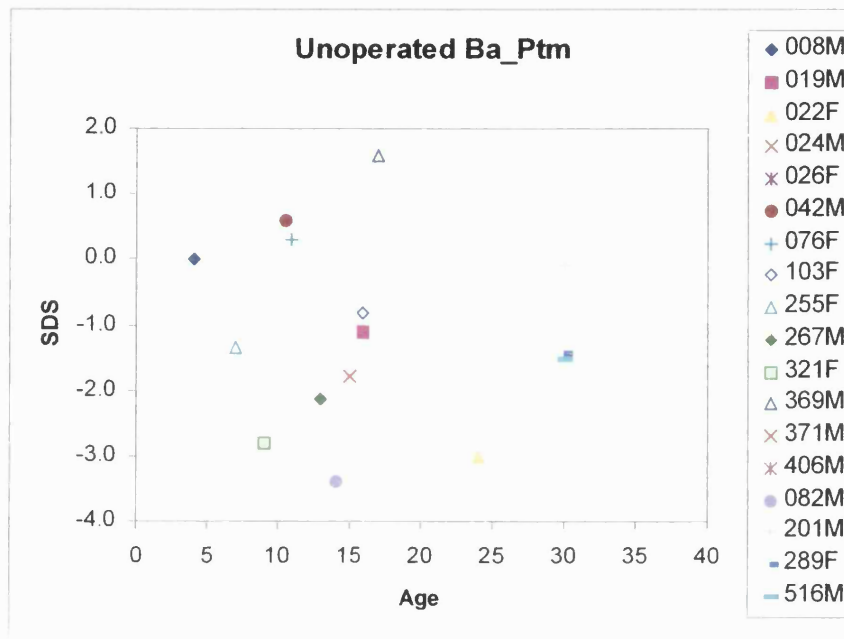
Fig. 5.1.6 Cross-sectional Unoperated Ans_Ptm - Maxillary Length
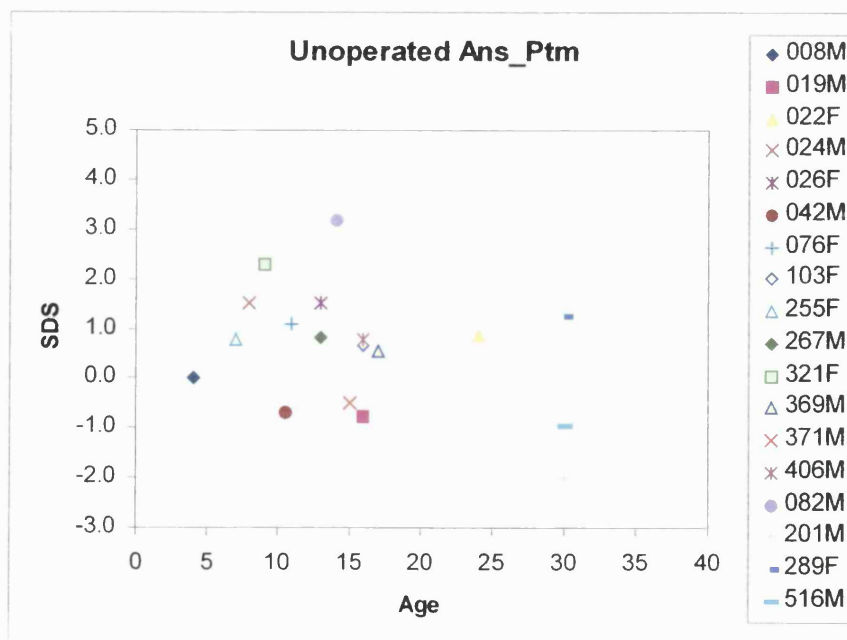
Fig.5.1.7 Cross-sectional Unop NaPg Maxillary/Mandibular Protrusion
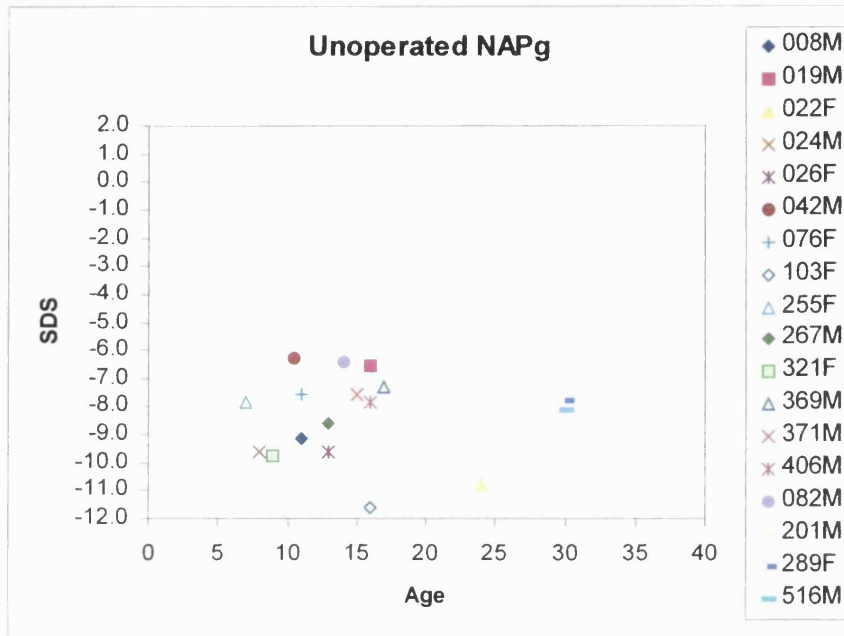
Fig. 5.1.8 Cross-sectional Unoperated SNB - Mandibular Protrusion
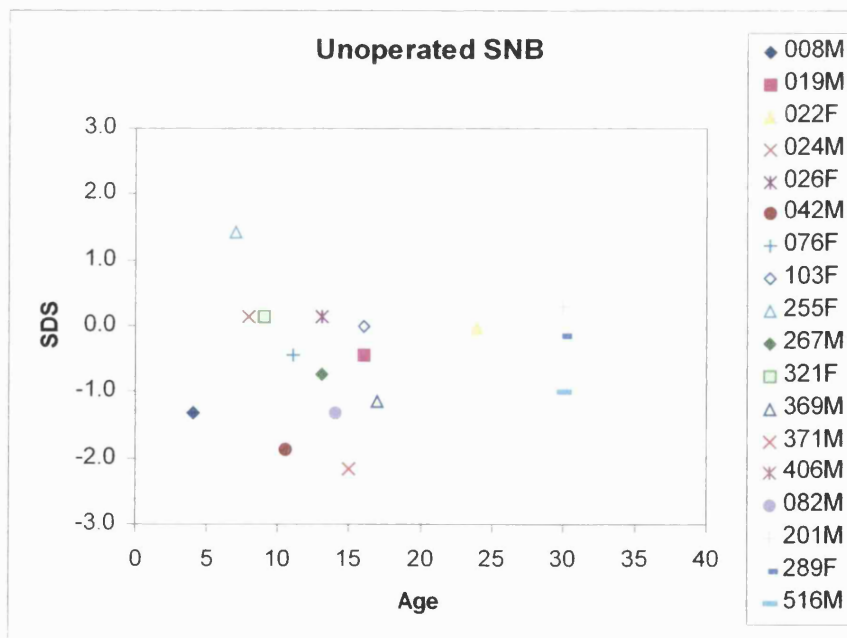
Fig. 5.1.9 Cross-sectional Unoperated Ar_TGO - Ramus Length
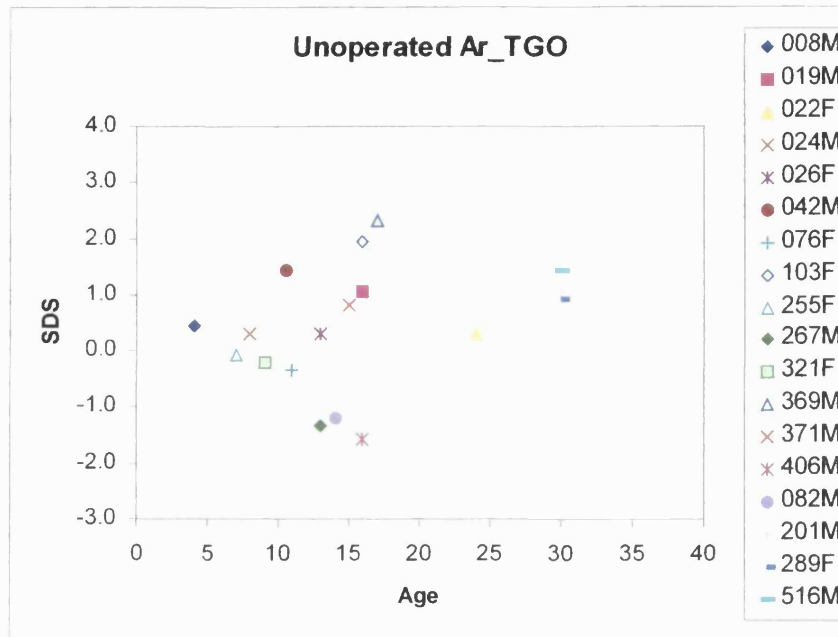
Fig. 5.1.10 Cross-sectional Unoperated TGO_Gn - Mandibular Length
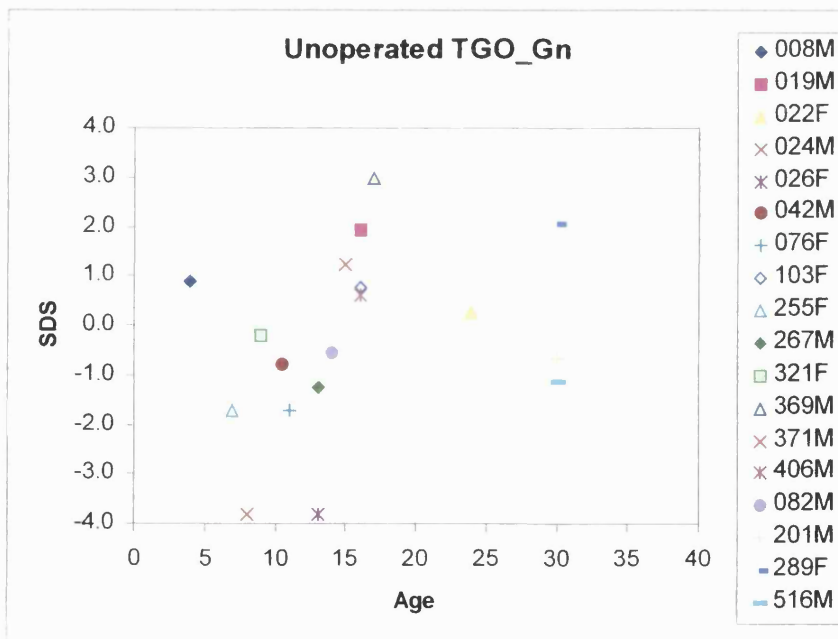
Fig. 5.1.11 Cross-sectional Unoperated ArTGOGn - Gonial Angle
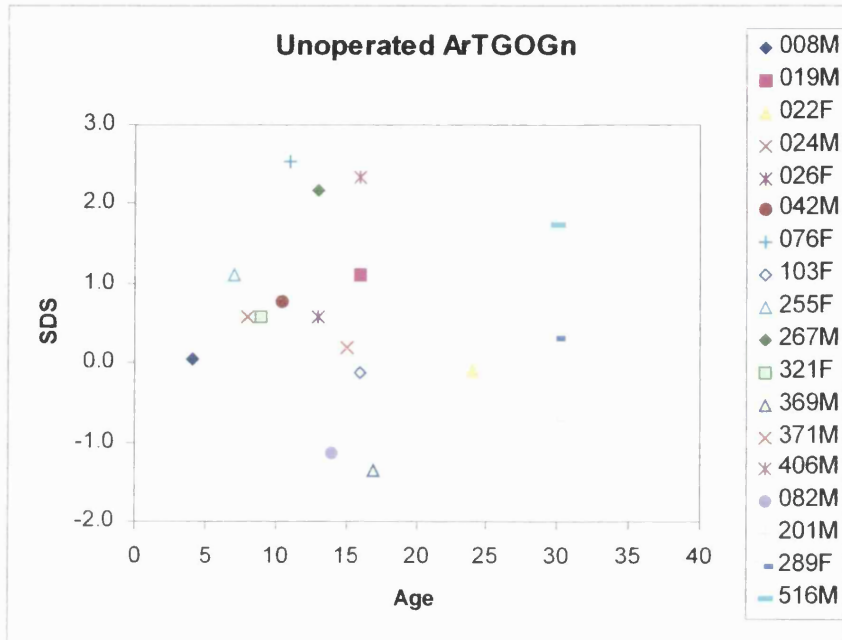
Fig. 5.1.12 Cross-sectional Unoperated Ar_Pg - Mandibular Length
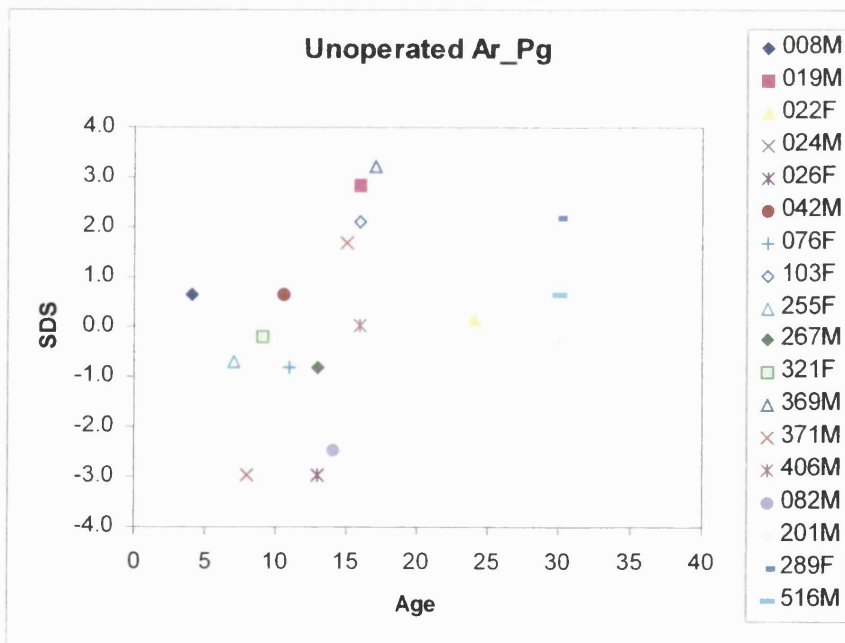
Fig. 5.1.13 Unoperated S_N_Ans - Upper Anterior Facial Height
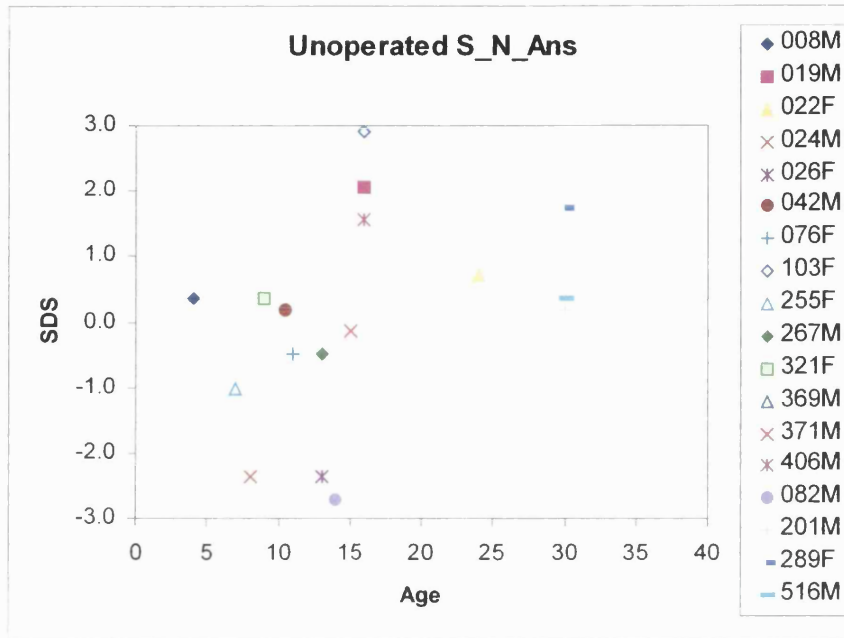
Fig. 5.1.14 Unoperated N_S_Ptm - Upper Posterior Facial Height
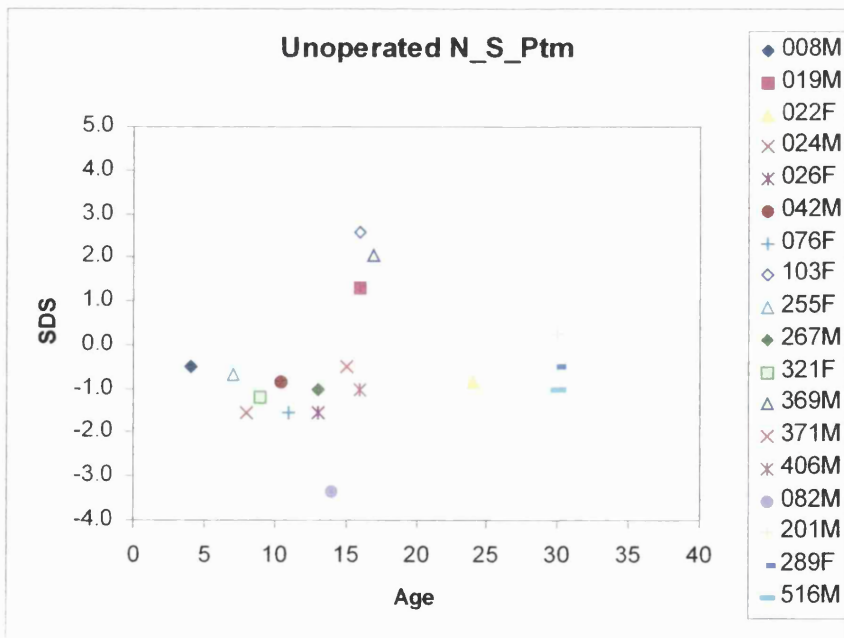
Fig. 5.1.15 Unoperated N_S_TGO - Total Posterior Facial Height
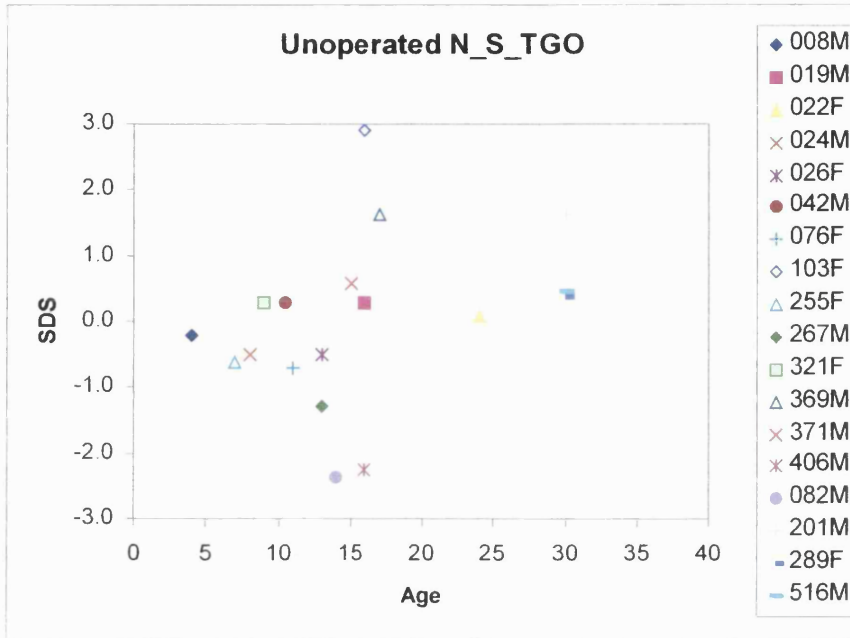
Fig. 5.1.16 Unoperated S_N_Gn - Total Anterior Facial Height
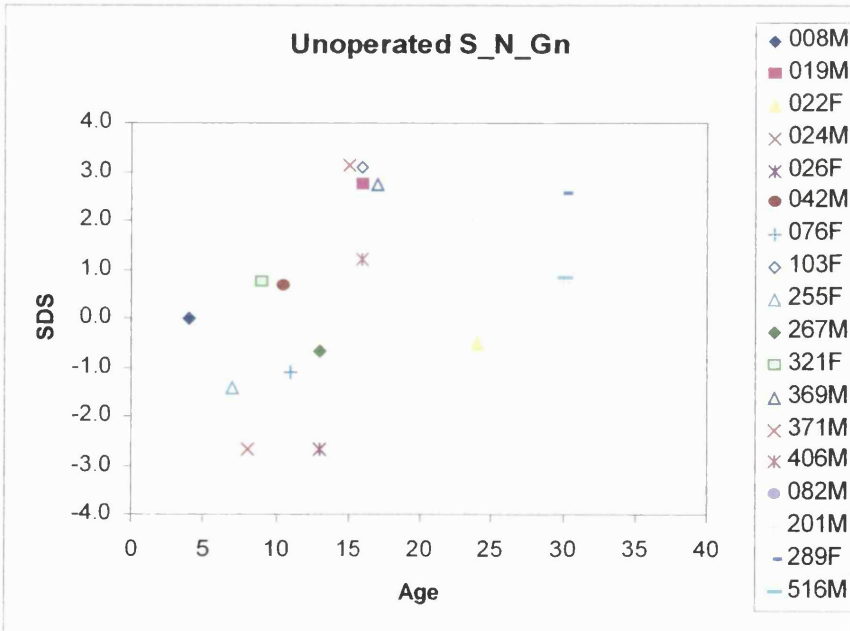
Fig. 5.1.17 Unoperated Gn_MT1/N_S - Mandibular Plane Angle
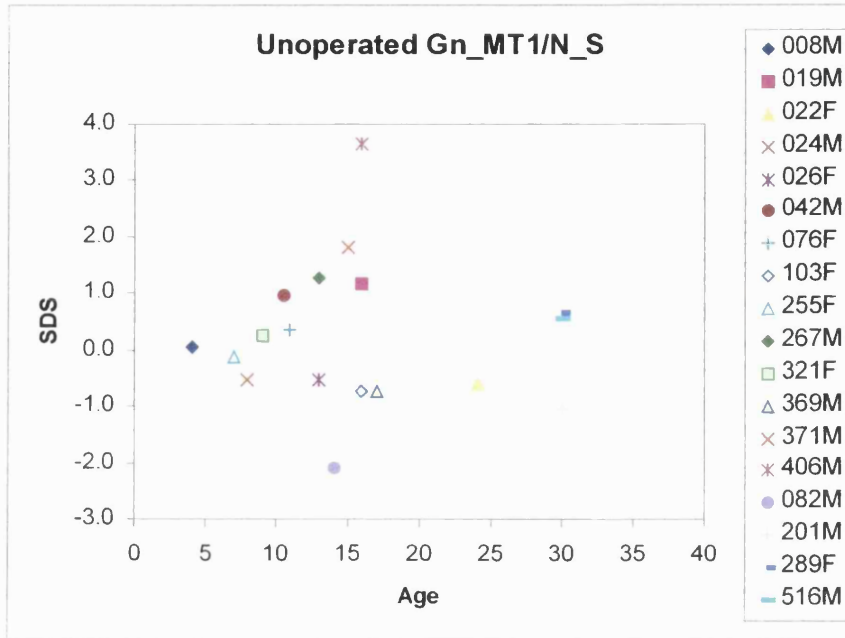
Fig. 5.1.18 Unoperated S_N/AS_IS - Upper Incisal Angle
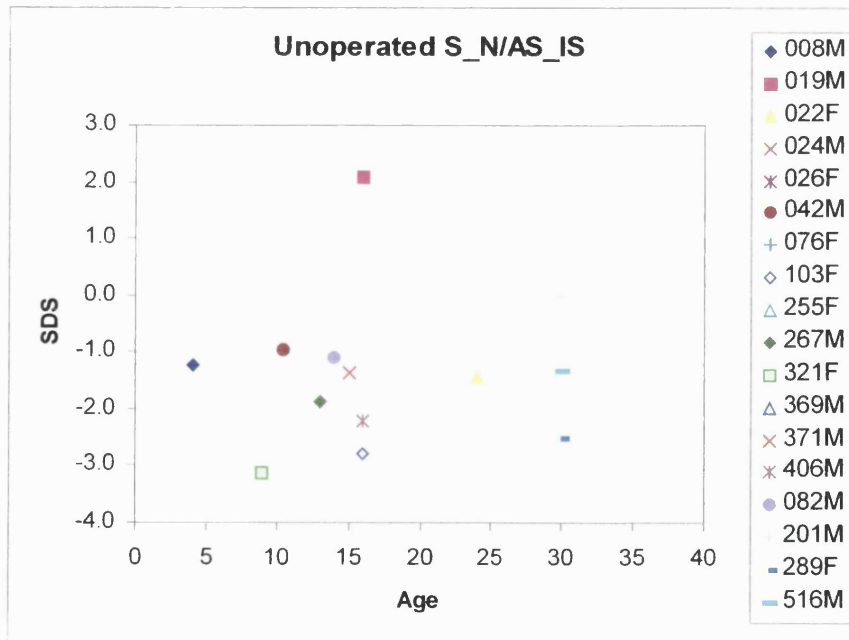
Fig. 5.1.19 Unoperated II_AI/Gn_MT1 - Lower Incisal Angle
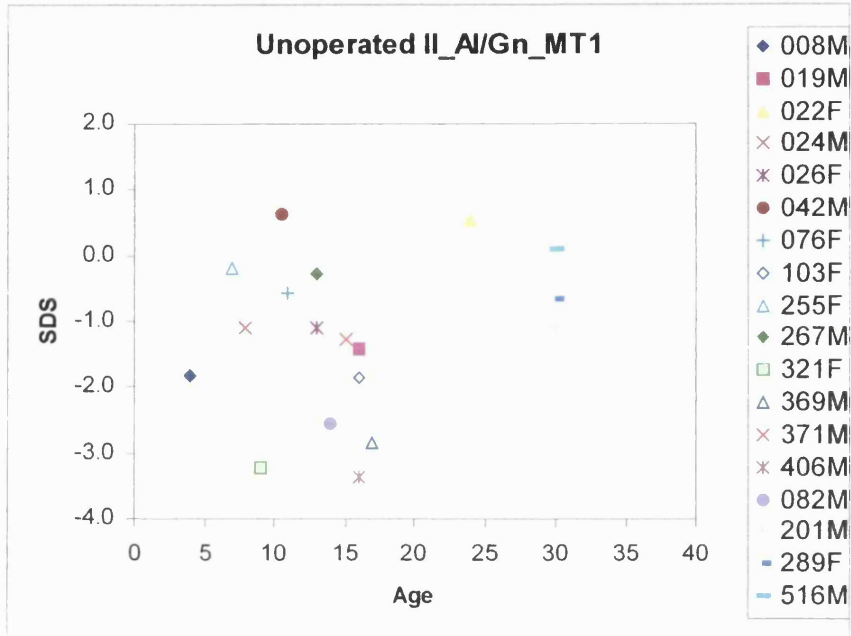
Fig. 5.1.20 Unoperated AS_IS/II_AI - Inter-incisal Angle
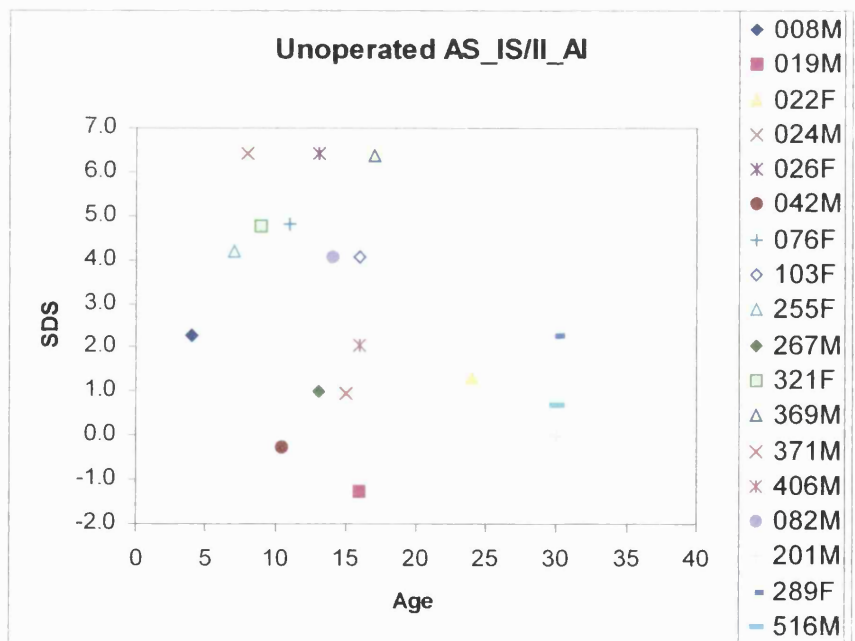
1. Cranial Base - the cranial base measures in the unoperated subject were smaller in both linear and angular dimensions in comparison to the Control population. Basion is more superior and anteriorly placed.

2. Maxillary Protrusion - the maxillary anterior protrusion angles showed some very unusual characteristics. SNA and the other premaxillary variables showed much greater angles in the unoperated group. These characteristics are due to the excessive protrusion of the premaxillary segment in the unoperated subject. Low values for SNAns, the angle of the anterior nasal spine in relation to the cranial base showed highly significant differences in comparison to the Controls; the position of Ans in the BCLP unoperated subject was more posteriorly placed.

The relationship of the posterior maxilla to the cranial base (NSPtm) was found to be within normal limits when compared to the Controls. Ba_Ptm was small compared to the non-cleft population; supporting the malposition of Basion in the BCLP Unop subject.

3. Facial Depth and Maxillary Length – the maxillary lengths were greater in the Unop subject.

4. Maxillary/Mandibular Protrusion - the relative maxillary/mandibular protrusion angle for the Unop subject showed lower values, a more reduced angle than in the Controls. The proclination of the premaxillary segment in relation to the mandible resulted in a reduced angle of convexity in the BCLP sample.

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5. Mandibular Protrusion – the mandibular protrusion angles were within the normal range in comparison to the Controls.

6. Mandibular Dimensions - Ar_TGO and ArTGOGn were within the normal range however, mandibular lengths, TGO_Gn and Ar_Pg, showed slightly longer lengths in comparison to the Controls in the Unop subject.

7. Facial Heights (Perpendicular distance) - Upper anterior facial height, total anterior and total posterior facial heights were all within a normal range. Upper Posterior facial height was shorter and the lower posterior facial height was larger than the Controls; suggesting the position of Ptm to be more superiorly placed within the cranium in the BCLP sample.

8. Mandibular Plane/Cranial Base Angle - the mandibular plane to cranial base angle was within a normal range.

9. Incisor relationships - the upper incisal angle was lower, more retroclined within the premaxilla in the Unop BCLP subject. The lower incisor inclination angle was lower than the Controls. Upper and lower incisors are both retroclined in the Unop BCLP subject. The inter-incisal angle was larger in the Unop BCLP sample.

D) The PostLip Repair

This section deals with the post lip repair subjects. Cross-sectional analysis examines individual subjects, at one point in time, who have had surgery to repair the cleft lip only. No surgery to the palate has been undertaken.

Fig. 5.2.1 Cross-sectional PostLip Ba_N - Cranial Base
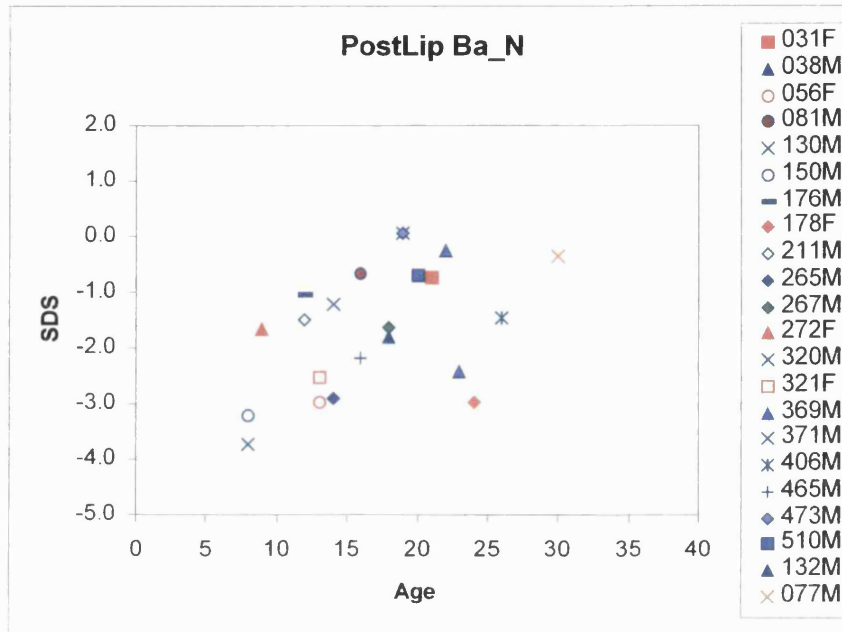
Fig. 5.2.2 Cross-sectional PostLip SNA - Maxillary Protrusion
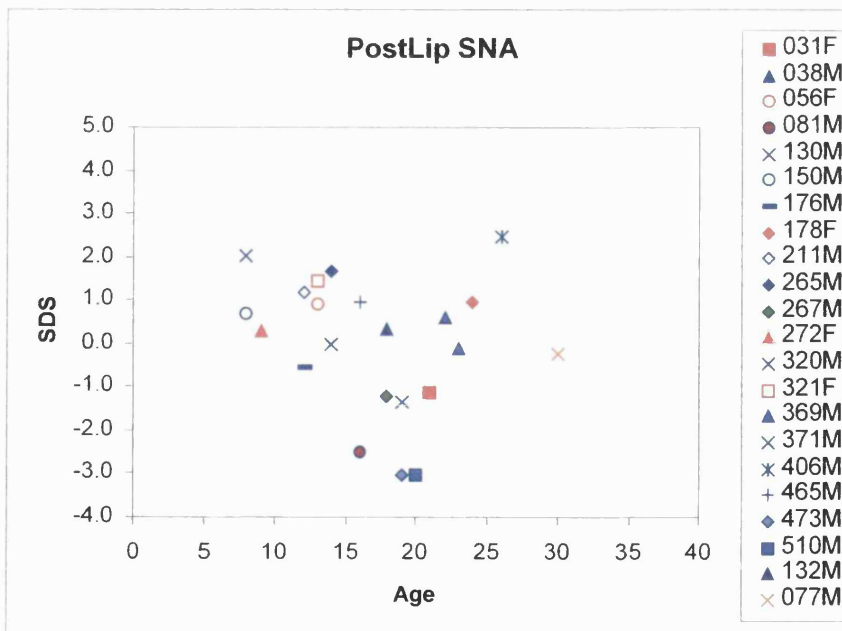
Fig. 5.2.3 Cross-sectional PostLip SNAns - Maxillary Protrusion
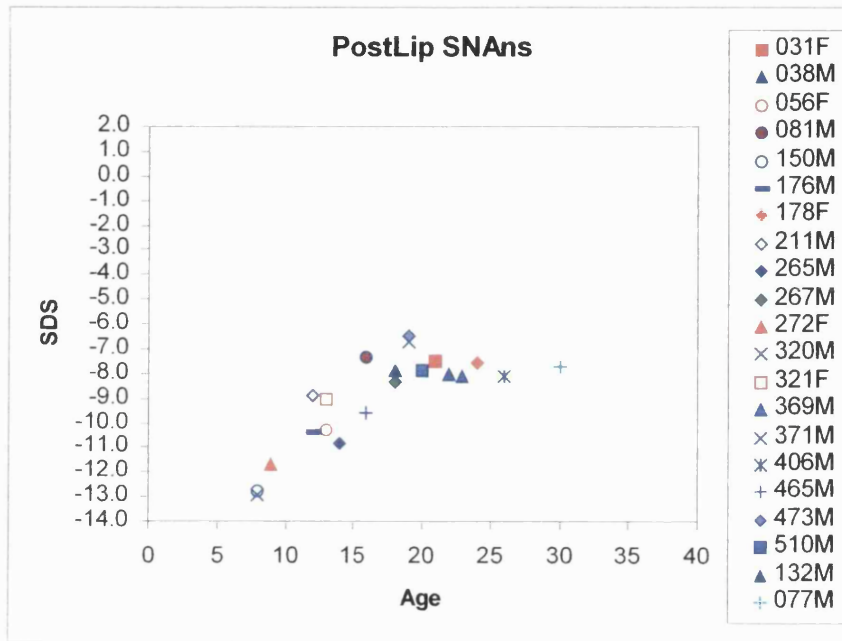
Fig. 5.2.4 Cross-sectional PostLip NSPtm - Maxillary Protrusion
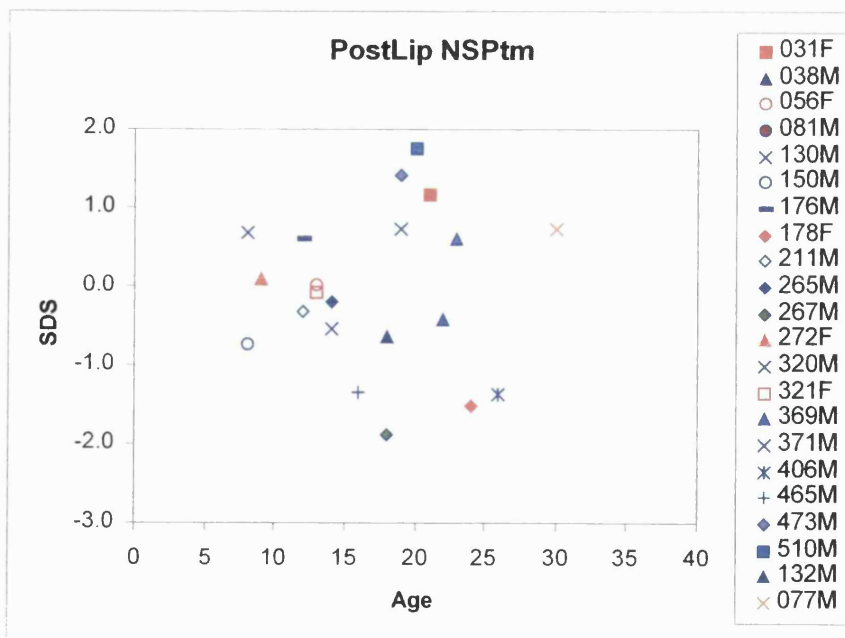
Fig. 5.2.5 Cross-sectional PostLip Ba_Ptm - Maxillary Protrusion
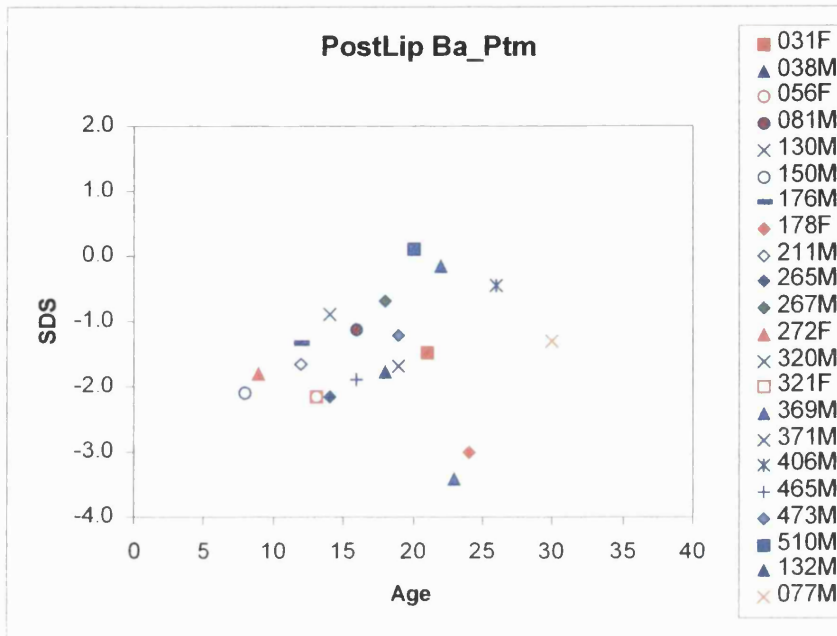
Fig. 5.2.6 Cross-sectional PostLip Ans_Ptm - Maxillary Length
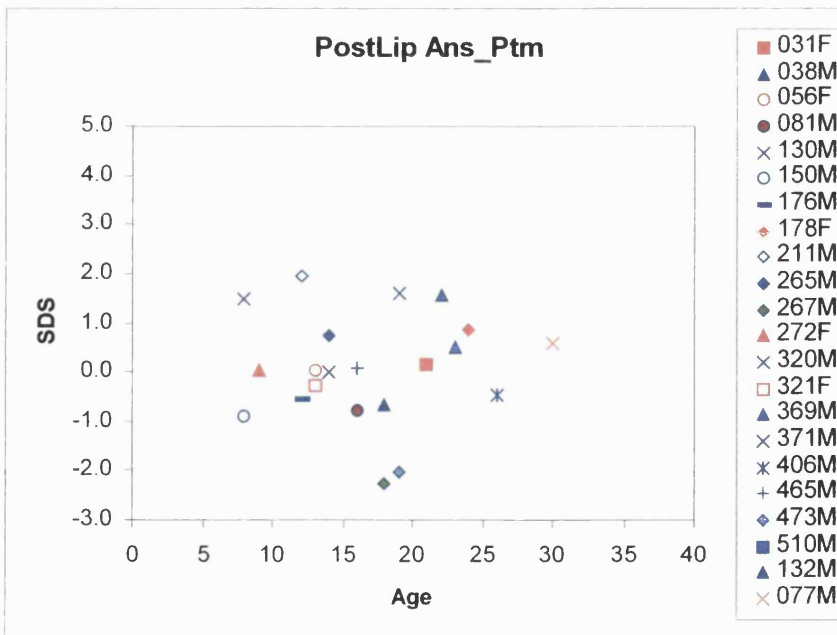
Fig. 5.2.7 Cross-sectional PostLip NaPg Maxillary/Mandibular Protrusion
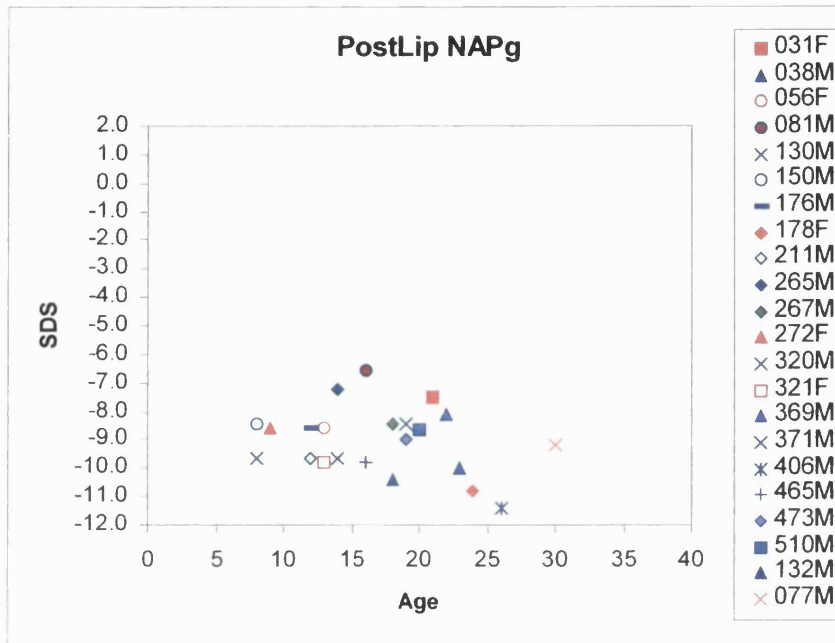
Fig. 5.2.8 Cross-sectional PostLip SNB - Mandibular Protrusion
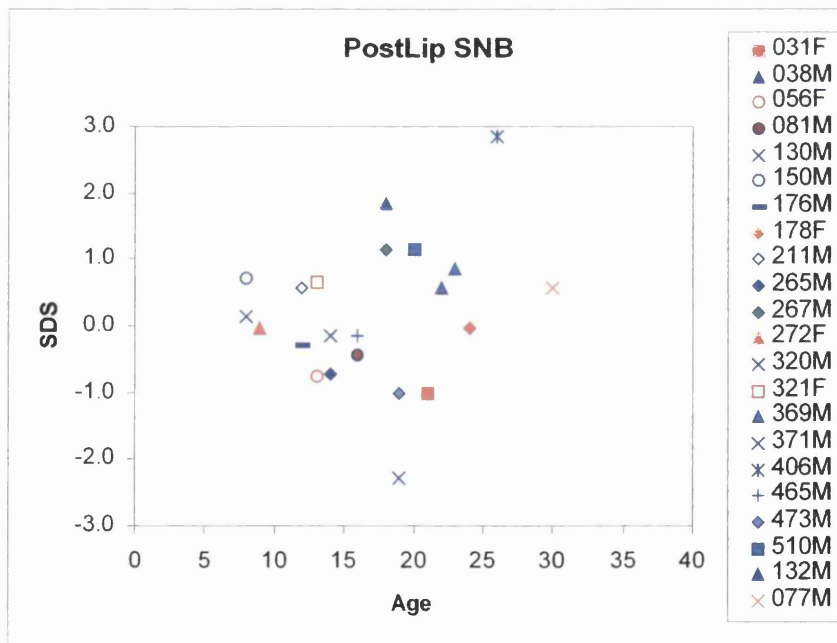
Fig. 5.2.9 Cross-sectional PostLip Ar_TGO - Ramus Length

PostLip Ar_TGO

Legend:
- ■ 031F
- ▲ 038M
- ○ 056F
- ● 081M
- ✕ 130M
- ○ 150M
- ▬ 176M
- ◆ 178F
- ◇ 211M
- ◆ 265M
- ◆ 267M
- ▲ 272F
- ✕ 320M
- □ 321F
- ▲ 369M
- ✕ 371M
- ✳ 406M
- + 465M
- ◆ 473M
- ■ 510M
- ▲ 132M
- ✕ 077M
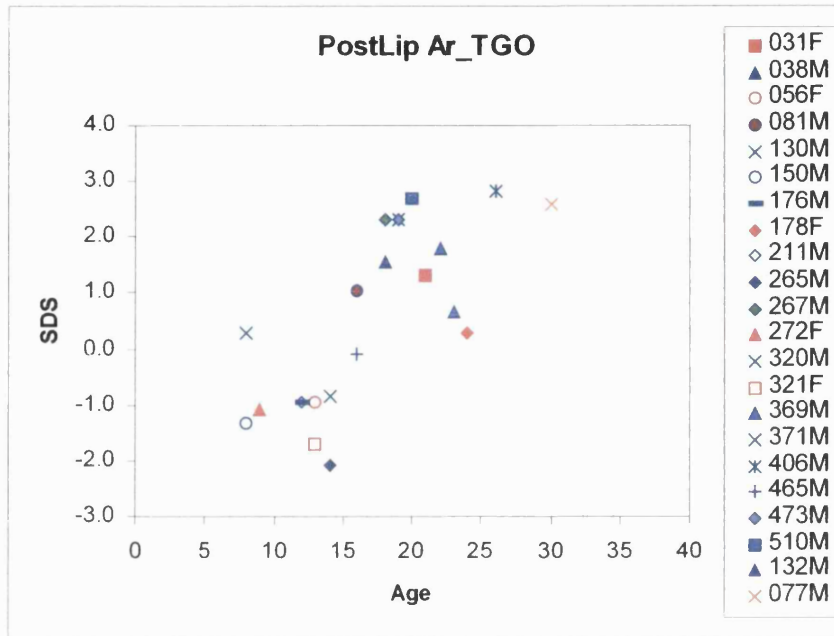
Fig. 5.2.10 Cross-sectional PostLip TGO_Gn - Mandibular Length

PostLip TGO_Gn

Legend:
- ■ 031F
- ▲ 038M
- ○ 056F
- ● 081M
- ✕ 130M
- ○ 150M
- ▬ 176M
- ◆ 178F
- ◇ 211M
- ◆ 265M
- ◆ 267M
- ▲ 272F
- ✕ 320M
- □ 321F
- ▲ 369M
- ✕ 371M
- ✳ 406M
- + 465M
- ◆ 473M
- ■ 510M
- ▲ 132M
- ✕ 077M

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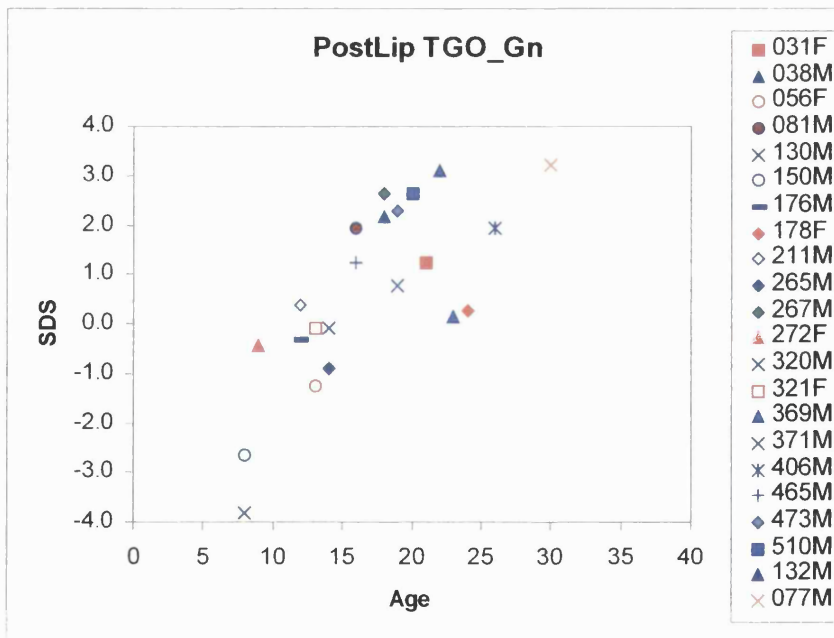
Fig. 5.2.11 Cross-sectional PostLip ArTGOGn - Gonial Angle
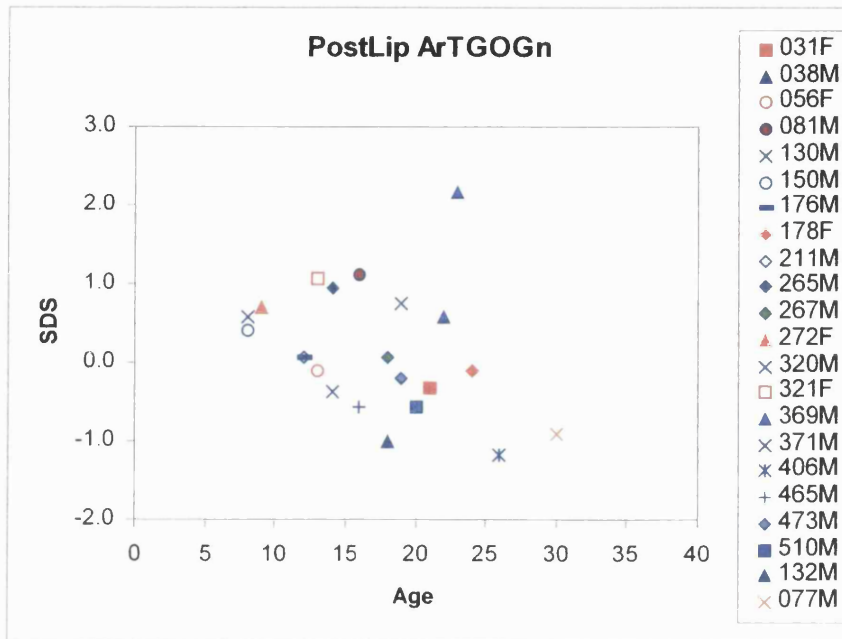
Fig. 5.2.12 Cross-sectional PostLip Ar_Pg - Mandibular Length
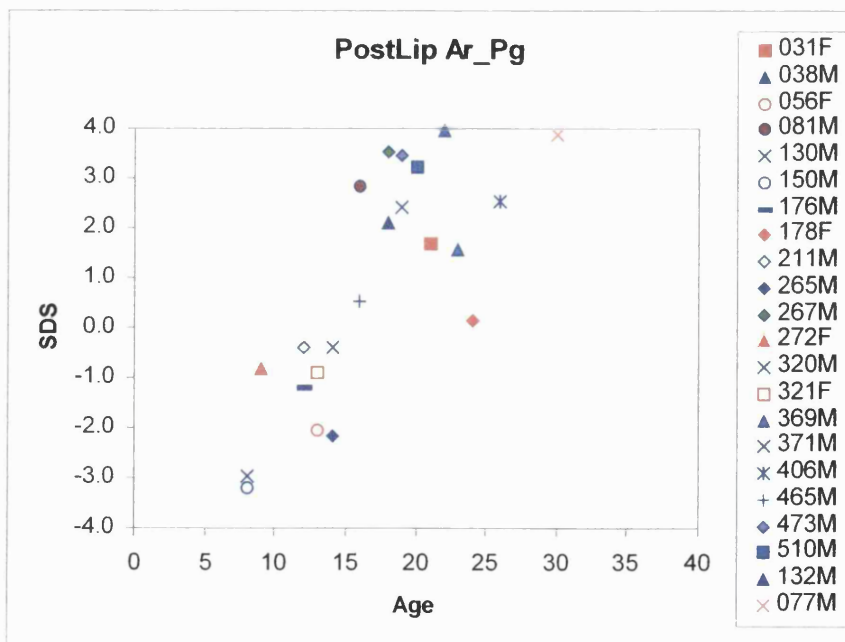
Fig. 5.2.13 PostLip S_N_Ans - Upper Anterior Facial Height
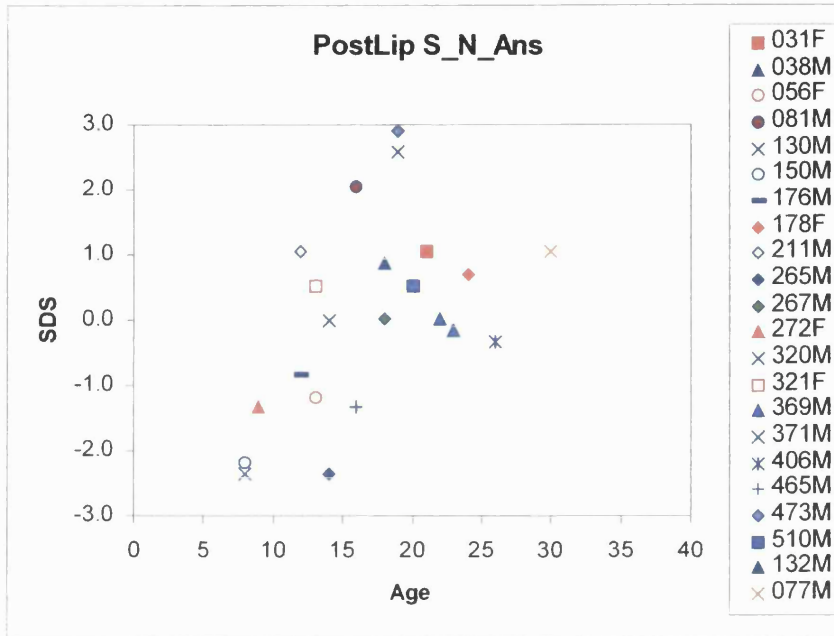
Fig. 5.2.14 PostLip N_S_Ptm - Upper Posterior Facial Height
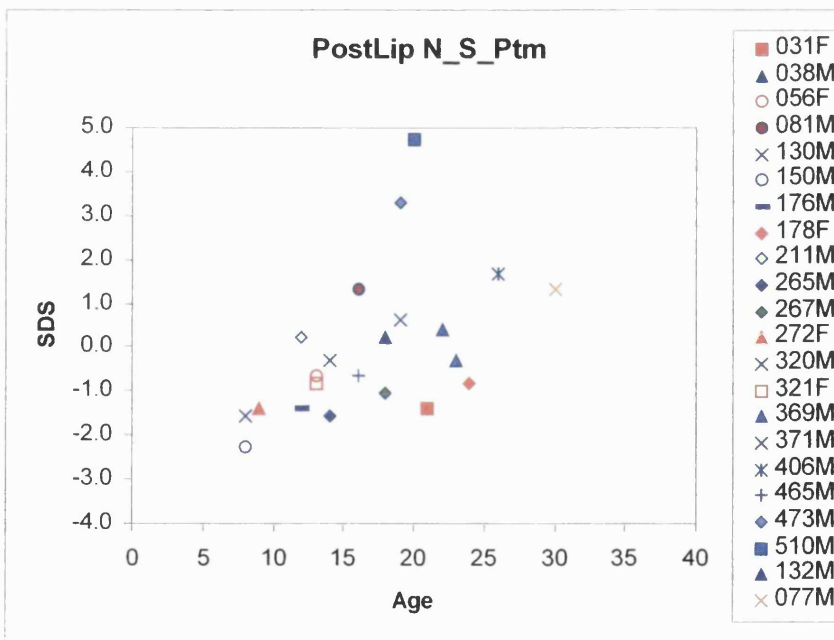
Fig. 5.2.15 PostLip N_S_TGO - Total Posterior Facial Height
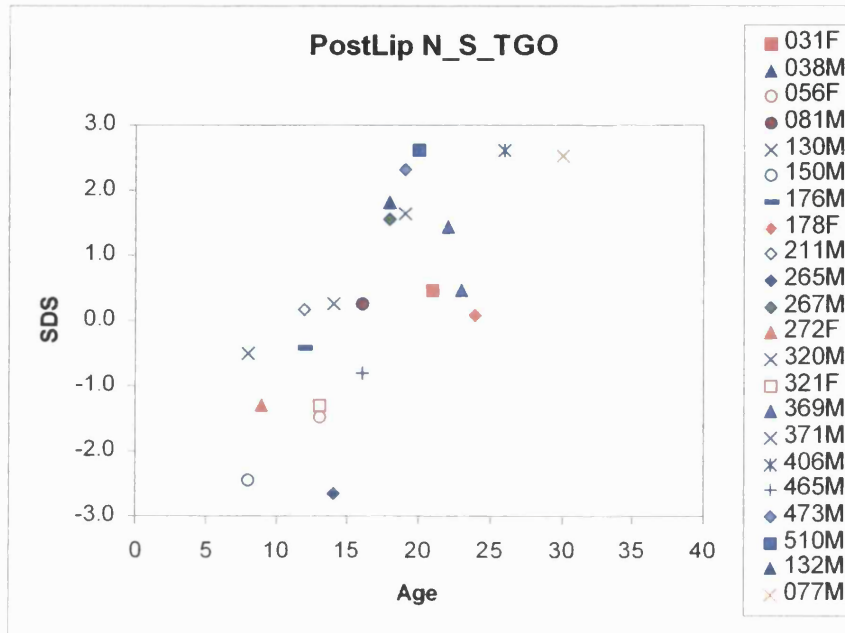
**Fig. 5.2.16 PostLip S_N_Gn - Total Anterior Facial Height**
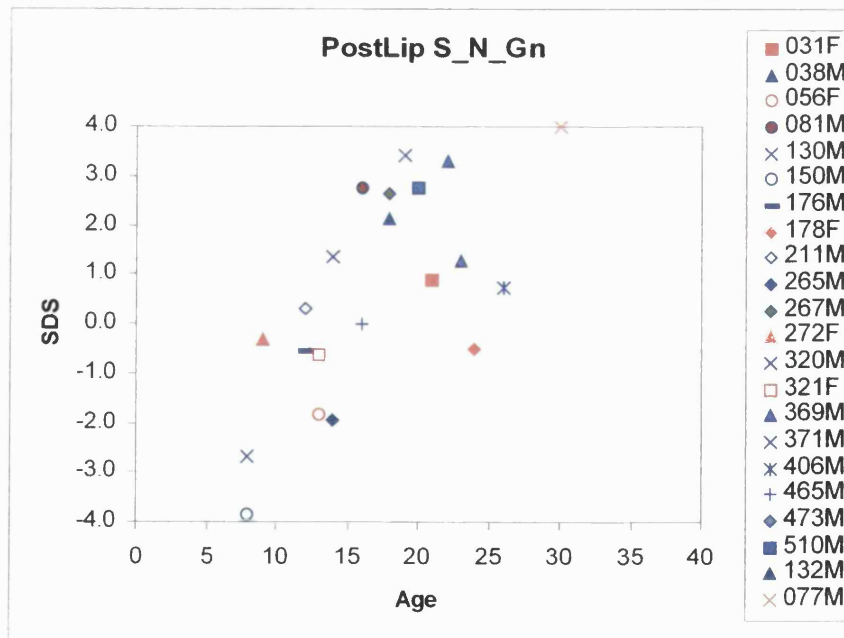
Fig. 5.2.17 PostLip Gn_MT1/N_S - Mandibular Plane Angle

PostLip Gn_MT1/N_S
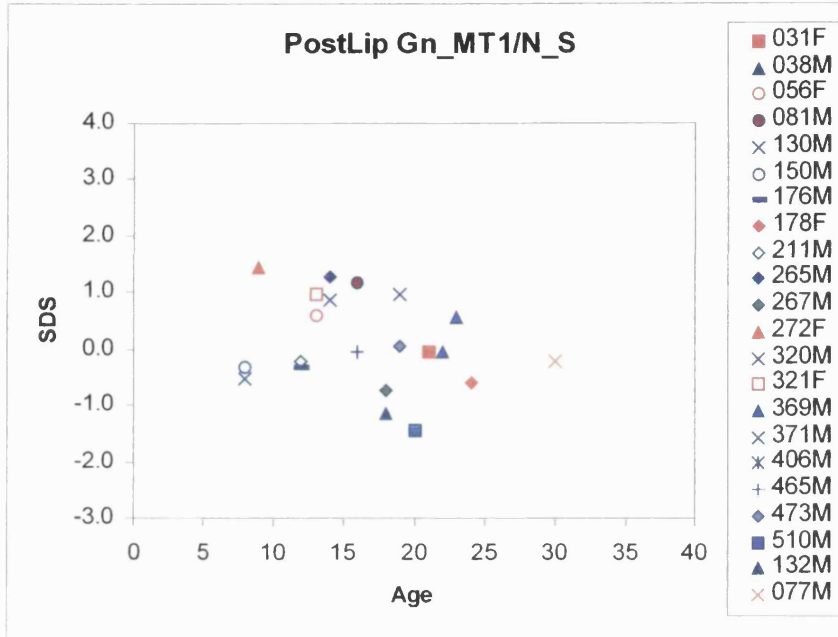
Fig. 5.2.18 PostLip S_N/AS_IS - Upper Incisal Angle

PostLip S_N/AS_IS
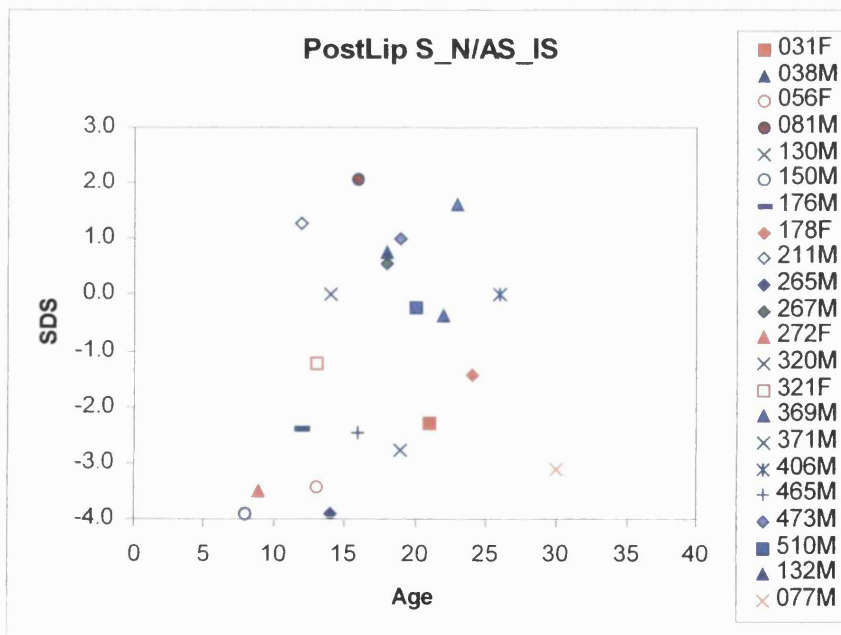
Fig. 5.2.19 PostLip II_AI/Gn_MT1 - Lower Incisal Angle

PostLip II_AI/Gn_MT1
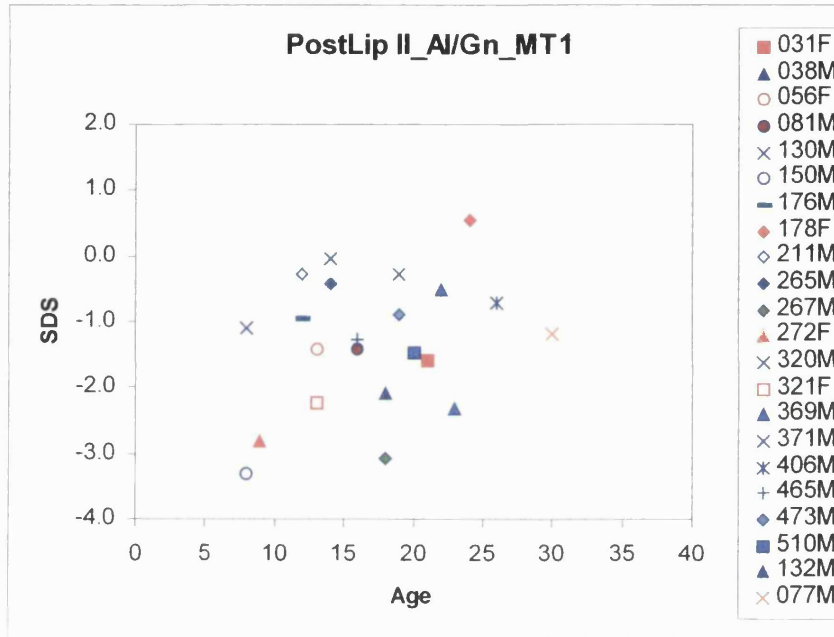
Fig. 5.2.20 PostLip AS_IS/II_AI - Inter-incisal Angle

PostLip AS_IS/II_AI
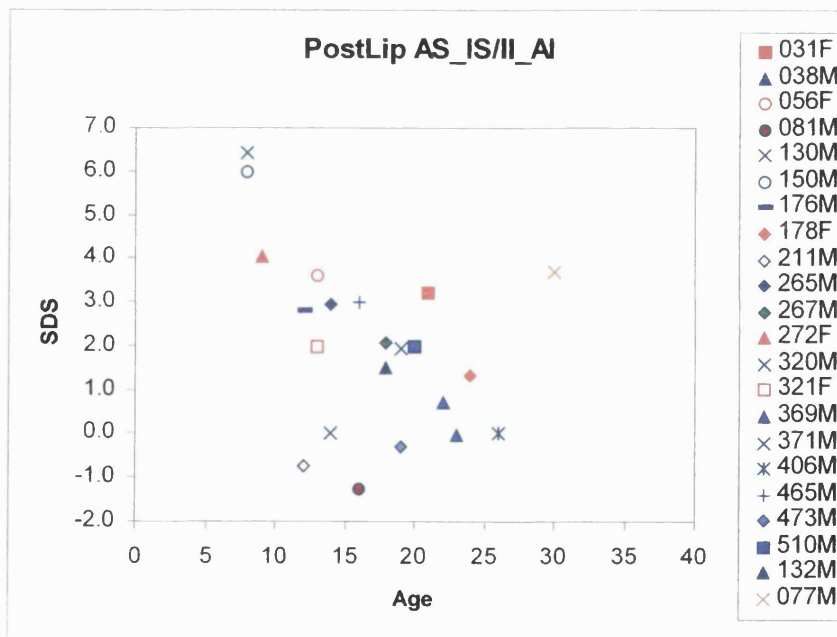
These results of the PostLip are presented as comparisons with the Unops.

1. Cranial Base - Cranial base measures in the PostLip group were smaller in both linear and angular dimensions. No effect was observed after lip repair in these variables.

2. Maxillary Protrusion - all maxillary protrusion angles showed a reduction after lip repair. SNA and all other dentoalveolar points on the premaxilla, presented with high values in the Unop group, which decreased after lip repair. SNAns was significantly decreased in relation to the Controls.

The posterior relationship of the maxilla remained the same as in the Unop subjects.

3. Facial Depth and Maxillary Length - maxillary length was reduced in the PostLip group. The overgrowth of the premaxilla in the unoperated subject was decreased after lip repair; however, the decreased values were still within a normal range for palatal length in comparison to the Controls.

4. Maxillary/Mandibular Protrusion - Low values were also presented by the facial convexity angle in the PostLip subject.

5. Mandibular Protrusion - mandibular protrusion angles were within the normal range in comparison to the Controls.

6. Mandibular Dimensions - Ar_TGO and ArTGOGn were within the normal range in comparison to the Controls. Mandibular lengths, TGO_Gn and Ar_Pg, remained slightly longer in length when compared to the Controls in the PostLip subject.

7. Facial Heights (Perpendicular distance) - Upper anterior facial height, total anterior and total posterior facial heights were all within a normal range with Controls. Upper Posterior facial height was shorter than the Control population; the position of Ptm remained more superiorly placed within the cranium in the BCLP PostLip group.

8. Mandibular Plane/Cranial Base Angle - the mandibular plane remained within a normal non-cleft range after lip repair as in the Unop subject.

9. Incisor relationships - the upper incisal angle was reduced slightly after lip repair in the PostLip BCLP subject. The lower incisal angle remained lower than the Controls. A reduction in the inter-incisal angle was noted.

E) The PostPal Repair

This section deals with the post palate repair subjects, the main substance of this thesis. Longitudinal analysis examines individual subjects, throughout their entire facial growth period, who have had surgery to repair the lip and palate. Each individual is plotted longitudinally, with a minimum of 2 or a maximum of 6 data points. The same colour and icon represents the same subject throughout the longitudinal study, the data points are joined to be able to analyze individual facial growth patterns. Five groups encompass a variety of palatoplasty timing, subdivided by the age at palate repair (Page 92).

A selection of the longitudinal facial growth variables and statistical analysis is presented in this results chapter. Full statistical analysis on every facial growth variable is provided as Appendix A (Page 314). A complete presentation of SDS graphs for all variables is attached as a CD in the back of the thesis. The longitudinal results are presented under the same 9 facial growth and morphology headings as previously (see Page 148).

The P value is the level of significance:

*	**0.01**	Statistically significant
**	**0.001**	Very Statistically significant
***	**0.0001**	Highly Statistically significant

1. Cranial Base

Four variables were analysed: Ba_N   S_N   Ba_S   BaSN

One example is presented Ba_N.

Fig. 5.3.1 PostPal Ba_N - Cranial Base
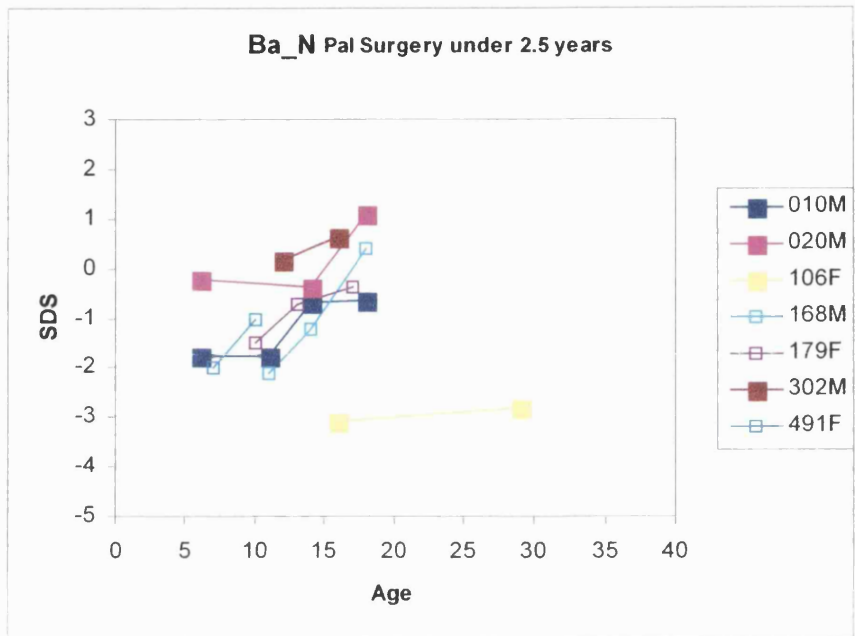
Fig. 5.3.2 PostPal Ba_N - Cranial Base
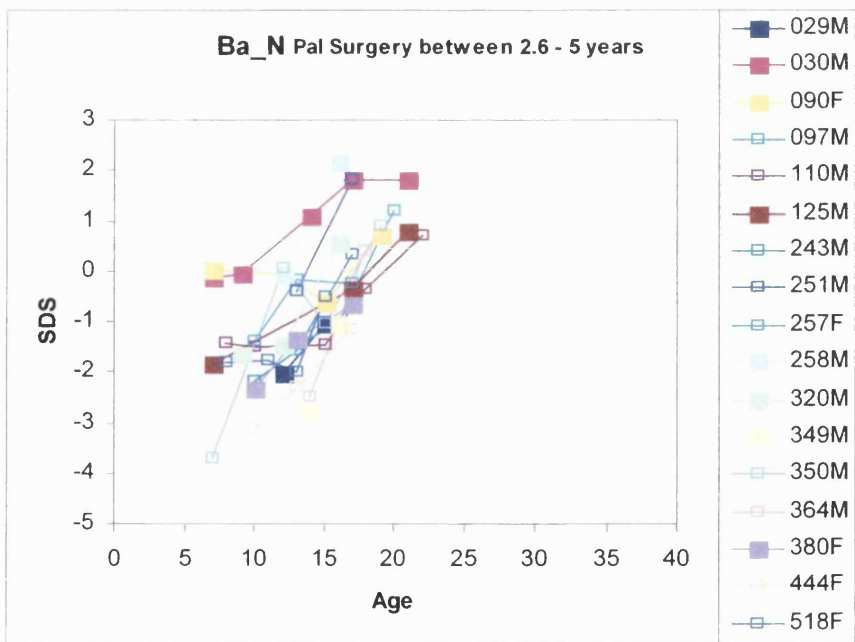
Fig. 5.3.3 PostPal Ba_N - Cranial Base

Ba_N Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
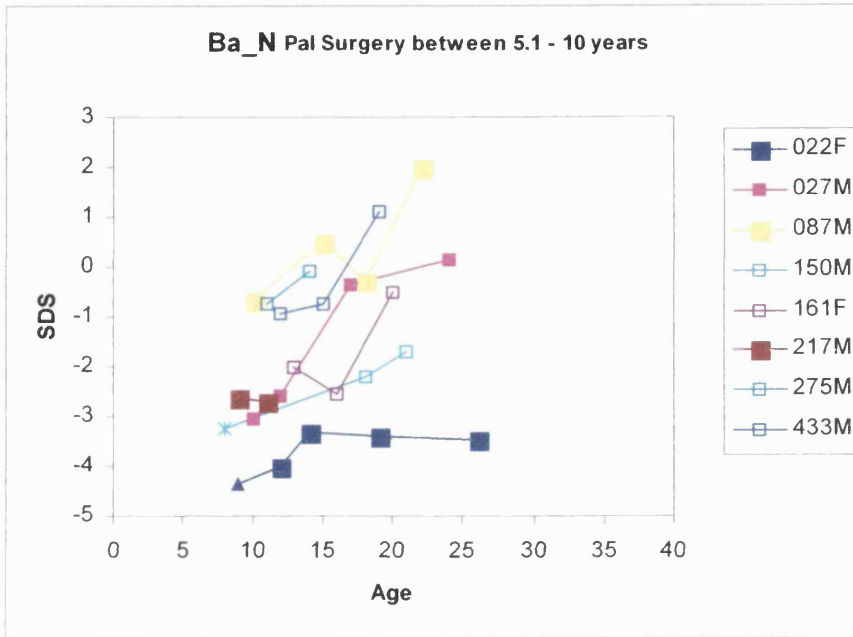
Fig. 5.3.4 PostPal Ba_N - Cranial Base

Ba_N Pal Surgery between 10.1 - 18 years

Legend: 026F, 056F, 081M, 130M, 176M, 265M, 321F, 437M, 465M
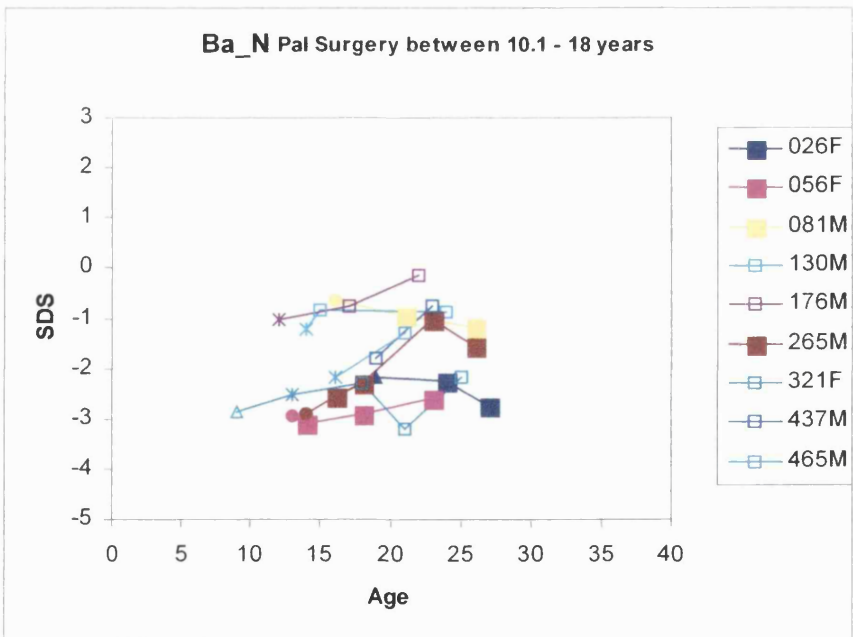
Fig. 5.3.5 PostPal Ba_N - Cranial Base

Ba_N Pal Surgery over 18.1 years

Legend:
- 042M
- 076M
- 132M
- 178F
- 371M
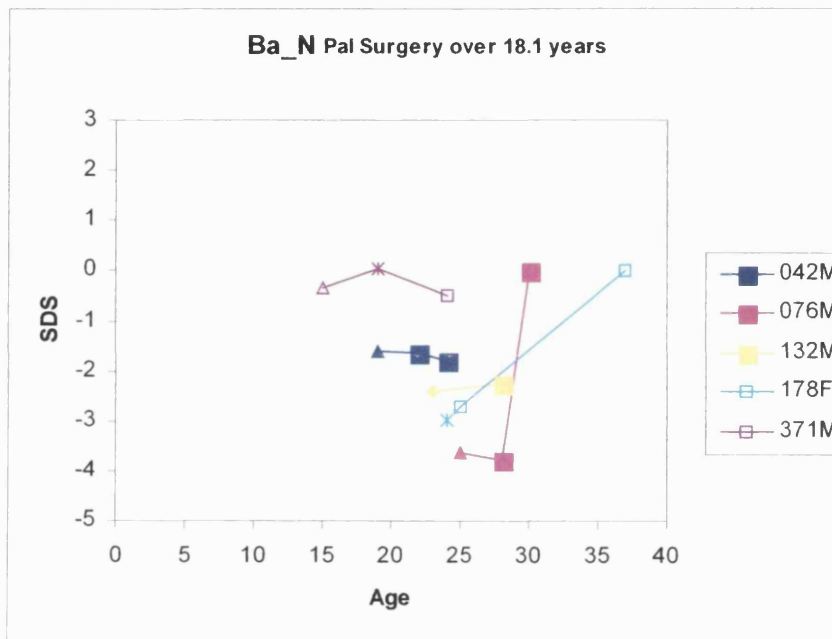
Statistical analysis

Question	Coeff.	t ratio	P value
1	-1.12	-9.36	**0.0001**
2	0.16	9.19	**0.0001**
3	-0.01	-2.82	**0.006**

1. Cranial Base

Cranial Base measures were significantly smaller than the Controls in both linear and angular dimensions for all post palatal surgery groups at the start of record collection.

The BCLP subjects grow at a much faster rate than the Control population. The average growth rate for the Control population would be a straight line at 0.

The rate of growth coefficient reduces significantly the older the subject is at palate repair. The earlier the palate repair is performed the more rapid growth coefficient is observed. Subject 168M, in Fig.5.3.1, exhibits a steeper rate of growth coefficient than subject 056F, in Fig.5.3.4.

In the Longitudinal study there were statistically different findings between the PostPal groups and the Control population.

	Question	P Value	Description
Ba_N	1	***	Very low mean SDS
	2	***	Steep rise with age
	3	**	Reduction in rate of rise with age at operation
Ba_S	1	***	Very low mean SDS
	2	***	Steep rise with age
	3	**	Reduction in rate of rise with age at operation
S_N	2	***	Steep rise with age
BaSN	1	***	Very low mean SDS

2. Maxillary Protrusion and relation to the Cranial Base

Eight variables were analysed:

SNA SNAS SNIS SNPR SNANS NSPTM Ba_PTM Ar_PTM

Four variables are presented: SNA, SNANS, NSPTM & Ba_Ptm.

Fig. 5.3.6 PostPal SNA - Maxillary Protrusion

SNA Pal Surgery under 2.5 years

Legend: 010M, 168M, 179F, 491F
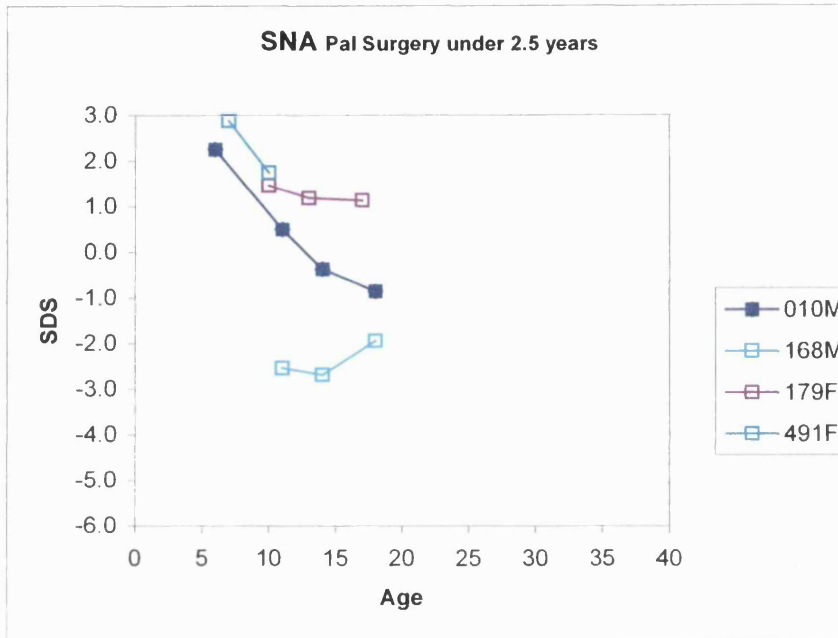
Fig. 5.3.7 PostPal SNA - Maxillary Protrusion

SNA Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F
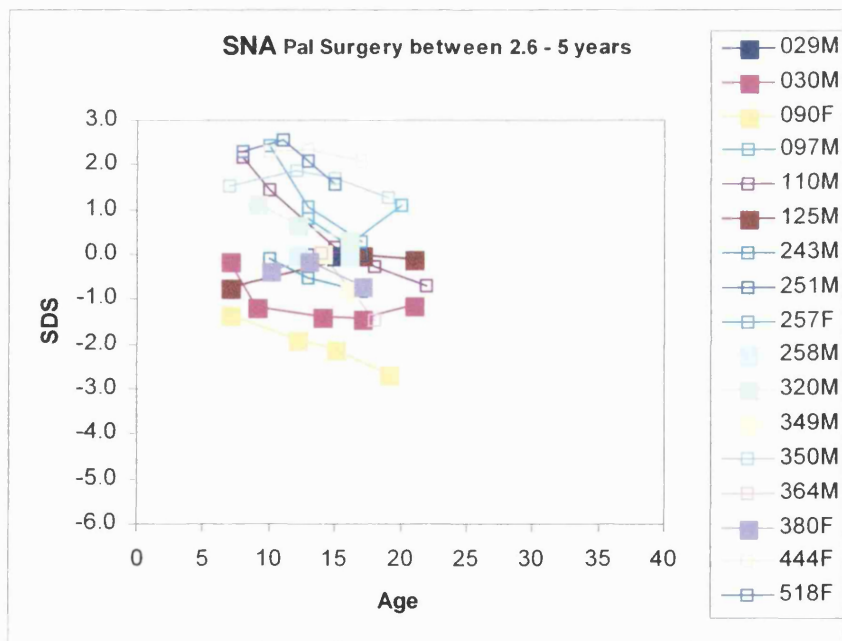
Fig. 5.3.8 PostPal SNA - Maxillary Protrusion

SNA Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M

5.3.9 PostPal SNA - Maxillary Protrusion

SNA Pal Surgery between 10.1 - 18 years

Legend: 056F, 081M, 176M, 265M, 321F, 437M, 465M
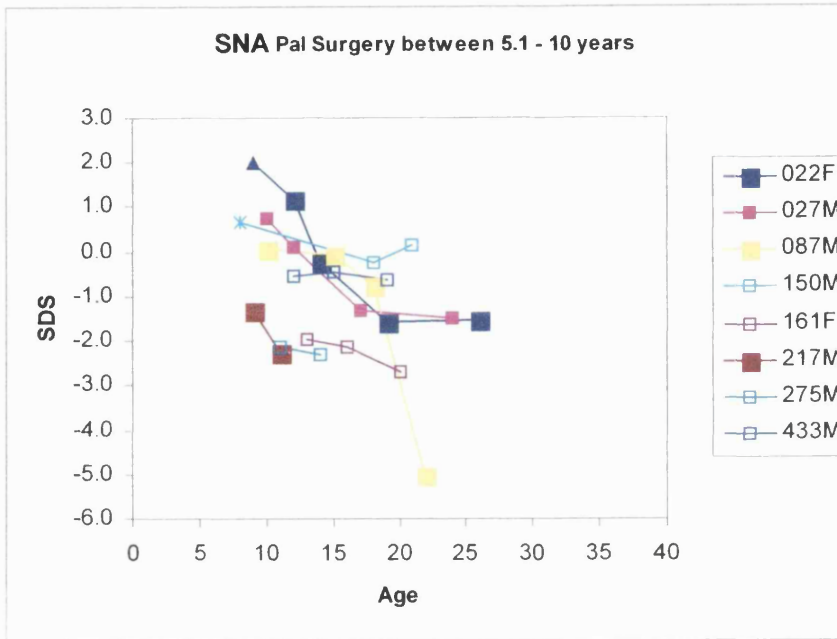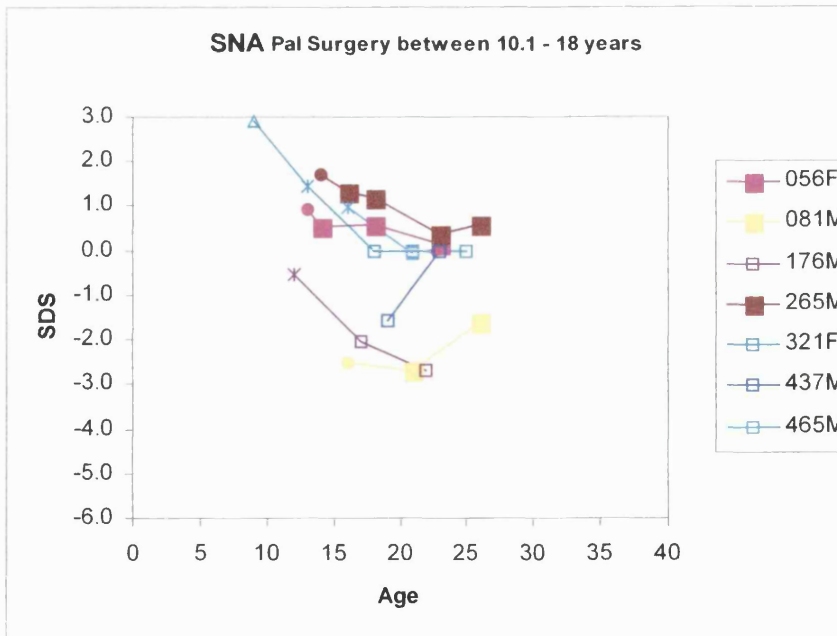
Fig. 5.3.10 PostPal SNA - Maxillary Protrusion

SNA Pal Surgery over 18.1 years
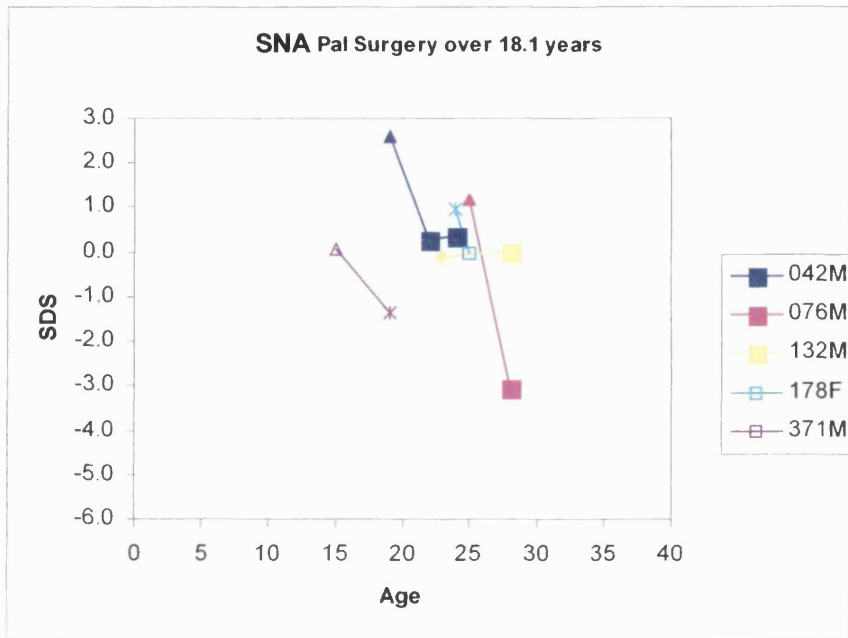
Statistical Analysis

Question	Coeff.	t ratio	P value
1	-0.1	-0.66	0.51
2	-0.13	-6.73	**0.0001**
3	-0.0003	0.05	0.96

Fig. 5.3.11 PostPal SNAns - Maxillary Protrusion

SNAns Pal Surgery under 2.5 years

Legend: 010M, 106F, 168M, 179F, 302M, 491F
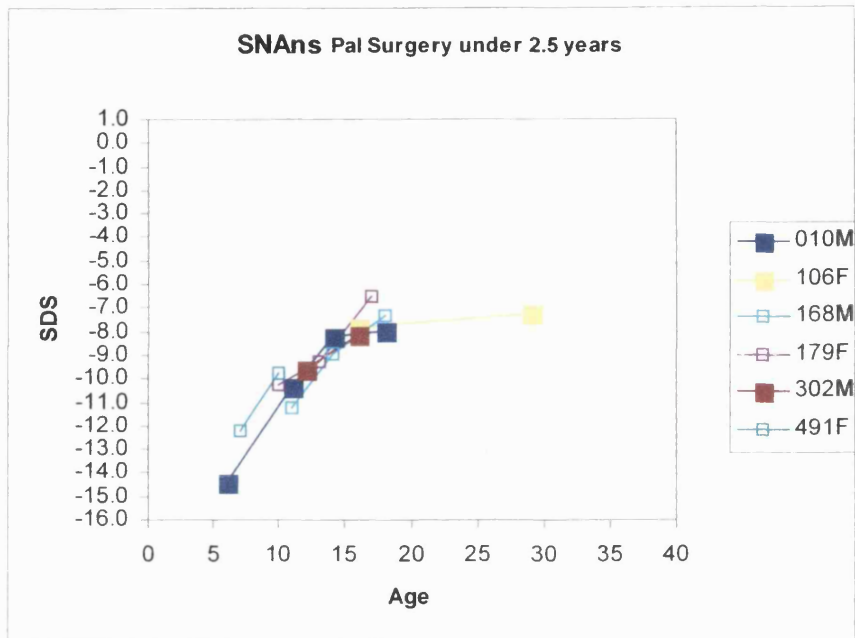
Fig. 5.3.12 PostPal SNAns - Maxillary Protrusion

SNAns Pal Surgery between 2.6 - 5 years

Legend: 030M, 090F, 097M, 110M, 125M, 243M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F
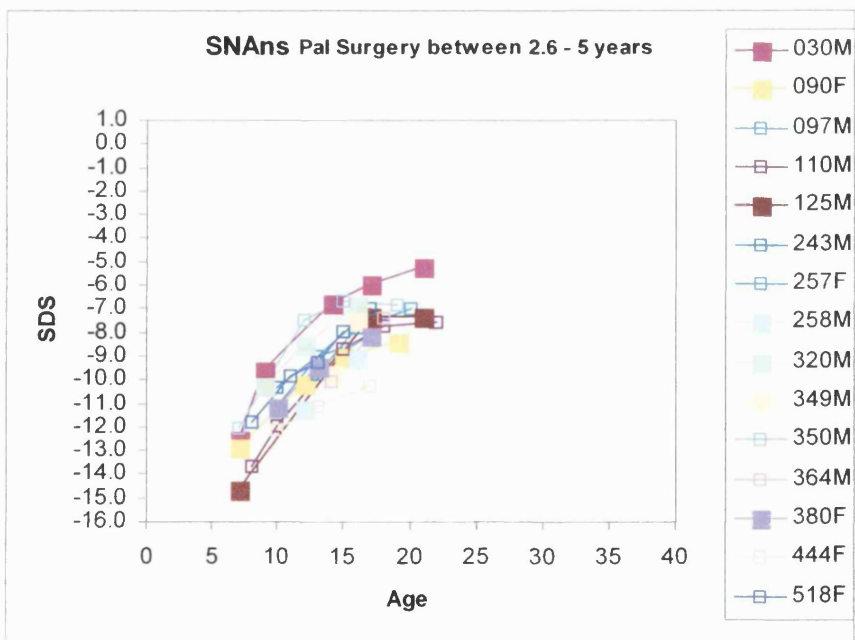
Fig. 5.3.13 PostPal SNAns - Maxillary Protrusion

SNAns Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
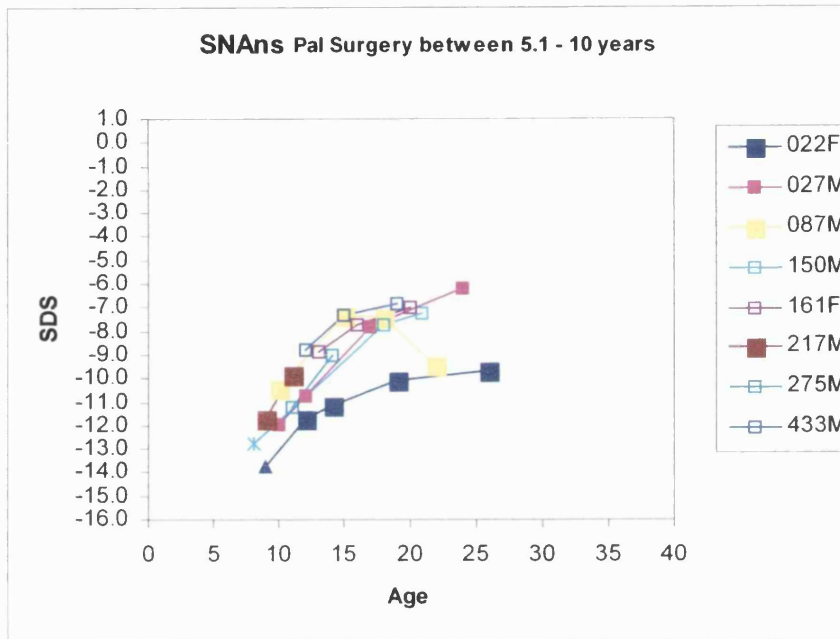
Fig. 5.3.14 PostPal SNAns - Maxillary Protrusion

SNAns Pal Surgery between 10.1 - 18 years

Legend: 056F, 081M, 176M, 265M, 321F, 437M, 465M
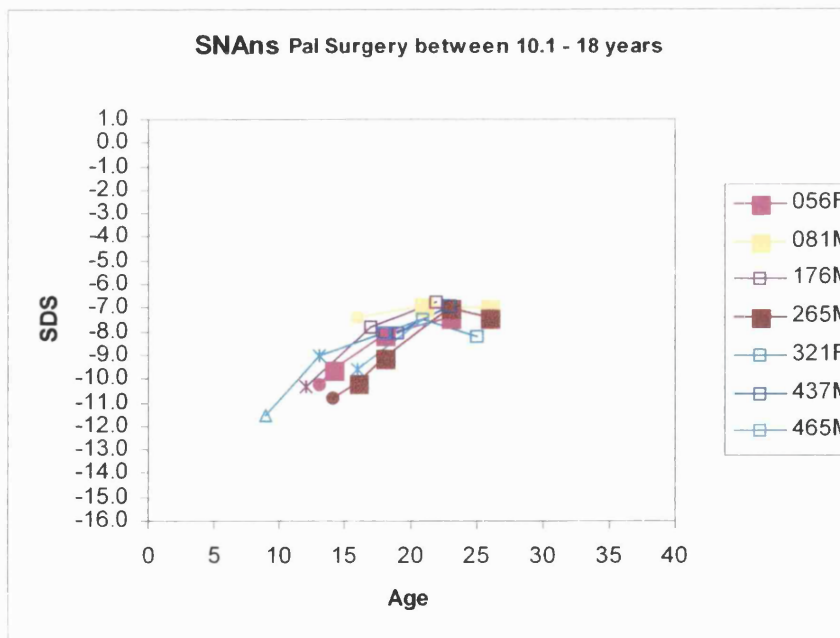
Fig. 5.3.15 PostPal SNAns - Maxillary Protrusion
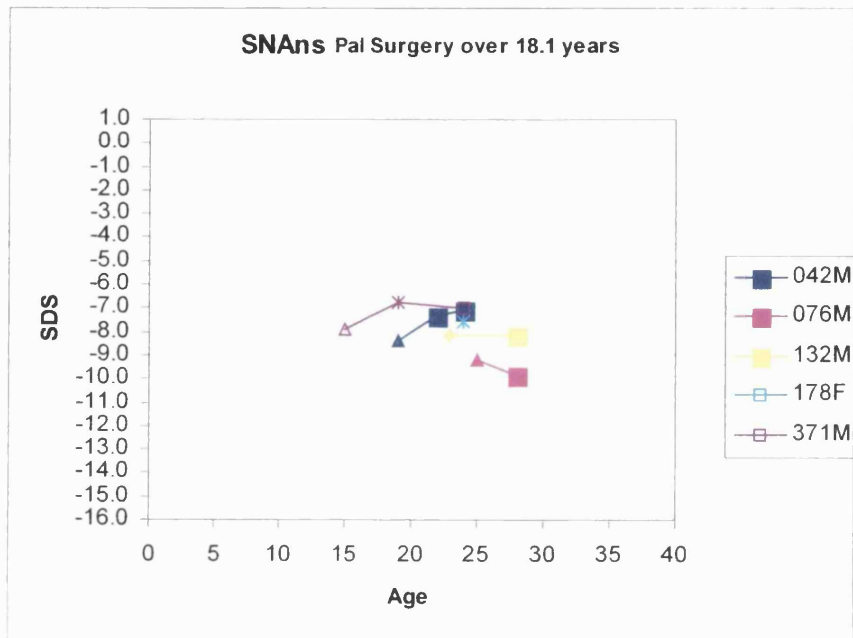
Statistical Analysis

Question	Coeff.	t ratio	P value
1	-8.99	-49.1	-0.0001
2	0.38	14.55	0.0001
3	-0.03	-3.73	0.0004

Fig. 5.3.16 PostPal NSPtm - Maxillary Protrusion

NSPtm Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
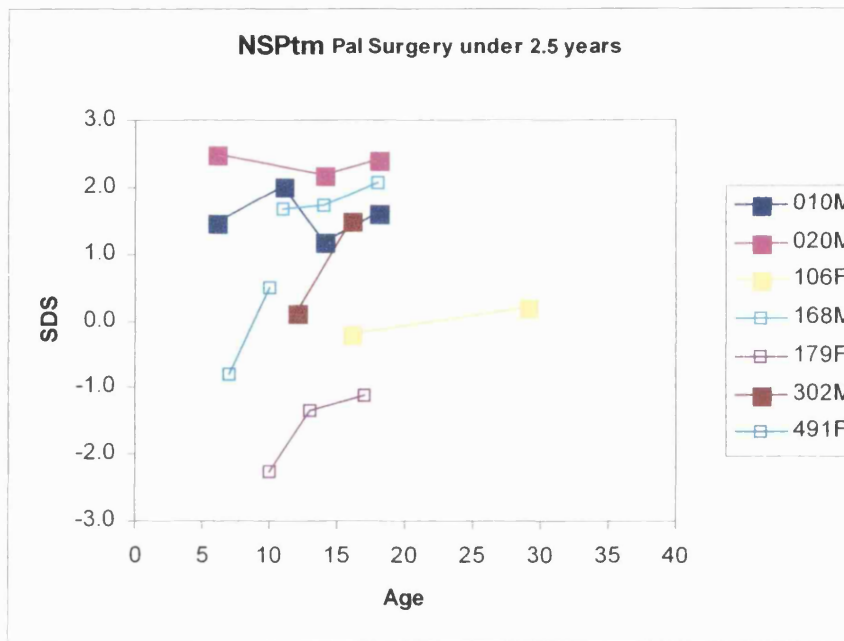
Fig. 5.3.17 PostPal NSPtm - Maxillary Protrusion

NSPtm Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F
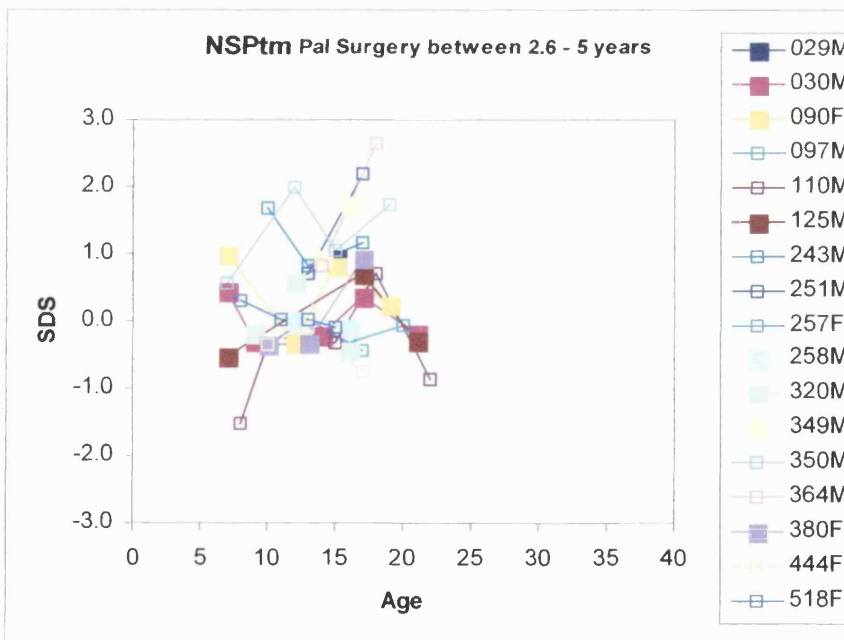
Fig. 5.3.18 PostPal NSPtm - Maxillary Protrusion

NSPtm Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M

X axis: Age
Y axis: SDS
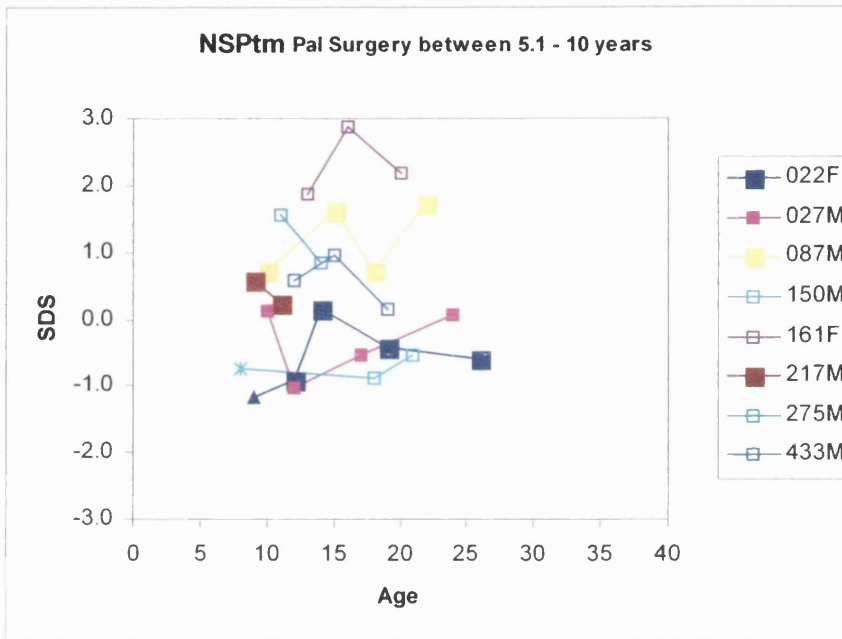
Fig. 5.3.19 PostPal NSPtm - Maxillary Protrusion

NSPtm Pal Surgery between 10.1 - 18 years

Legend: 026F, 056F, 081M, 130M, 176M, 265M, 321F, 437M, 465M

X axis: Age
Y axis: SDS
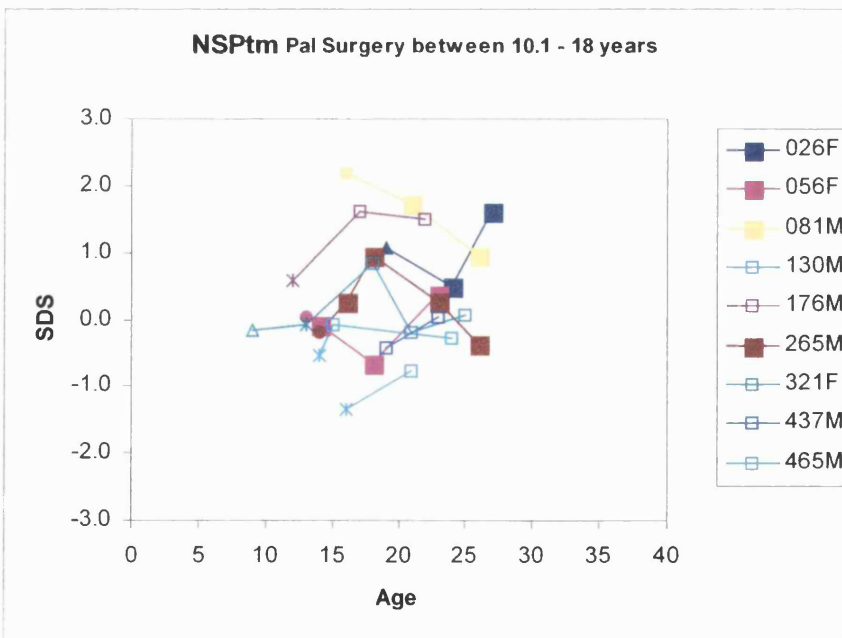
Fig. 5.3.20 PostPal NSPtm - Maxillary Protrusion

NSPtm Pal Surgery over 18.1 years
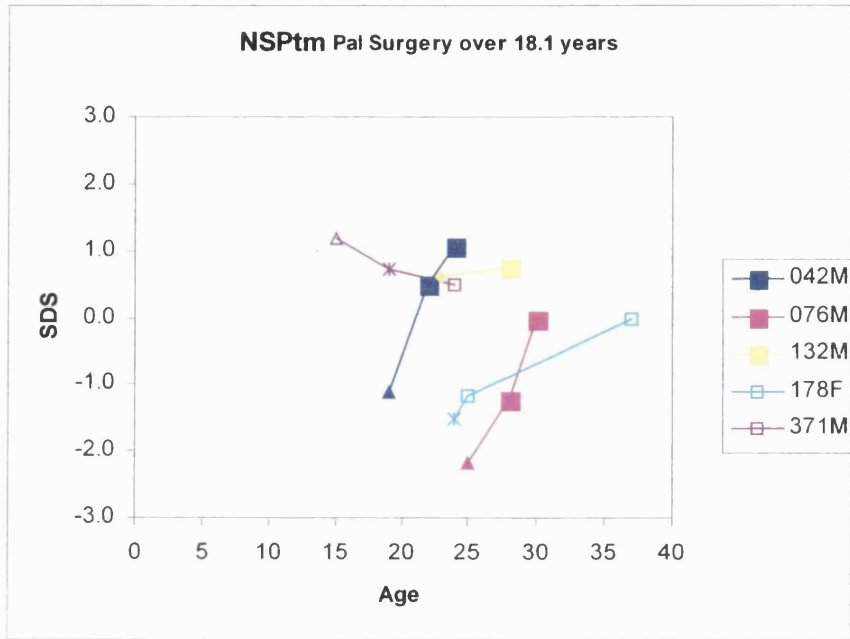
Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.43	5.01	**0.0001**
2	0.02	1.29	0.20
3	-0.004	-1.15	0.25

Fig. 5.3.21 PostPal Ba_Ptm - Maxillary Protrusion

Ba_Ptm Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
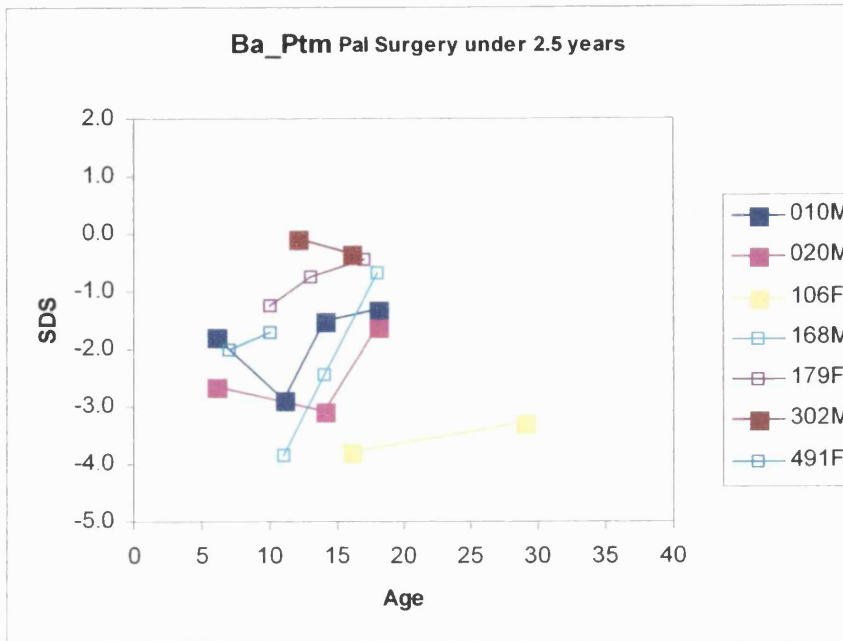
Fig. 5.3.22 PostPal Ba_Ptm - Maxillary Protrusion

Ba_Ptm Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F

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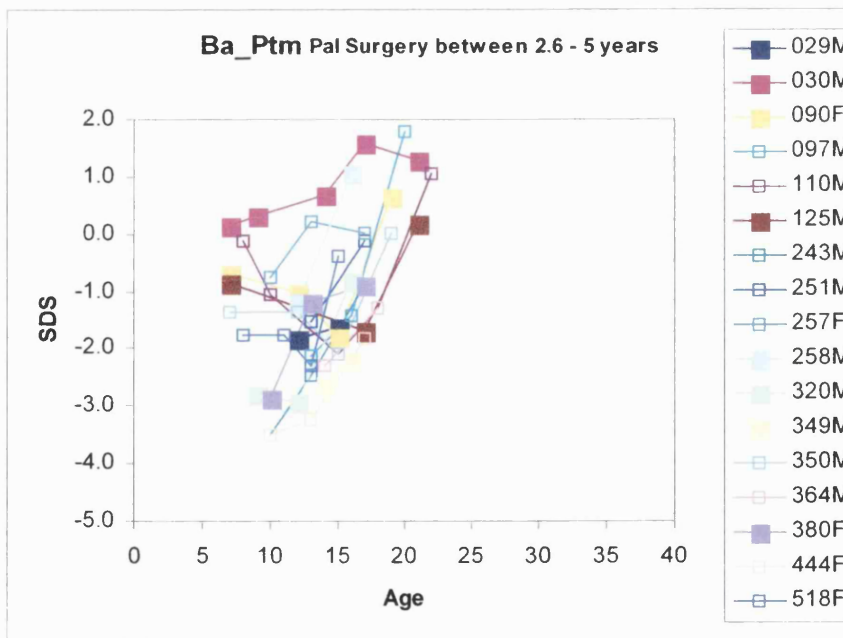
Fig. 5.3.23 PostPal Ba_Ptm - Maxillary Protrusion

Ba_Ptm Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
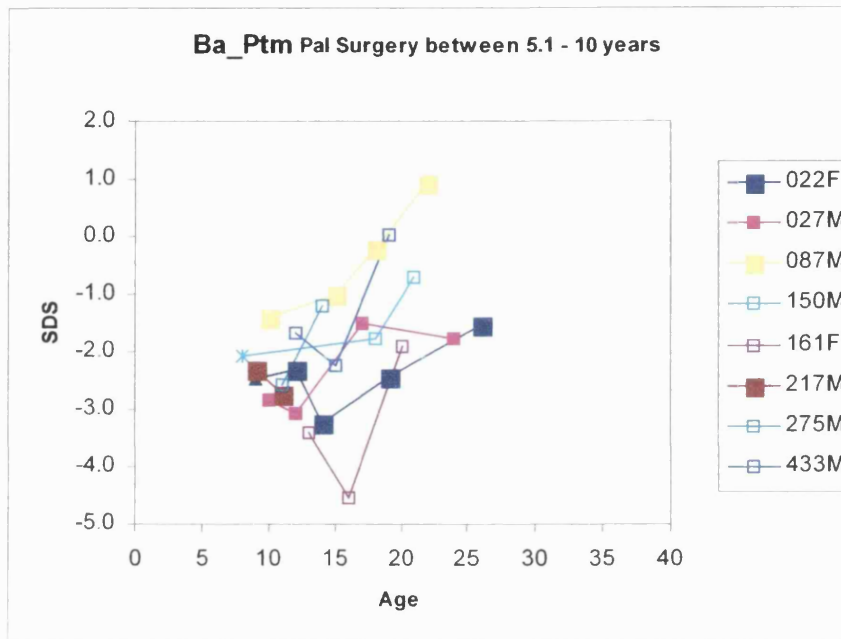
Fig. 5.3.24 PostPal Ba_Ptm - Maxillary Protrusion

Ba_Ptm Pal Surgery between 10.1 - 18 years

Legend: 026F, 056F, 081M, 130M, 176M, 265M, 321F, 437M, 465M
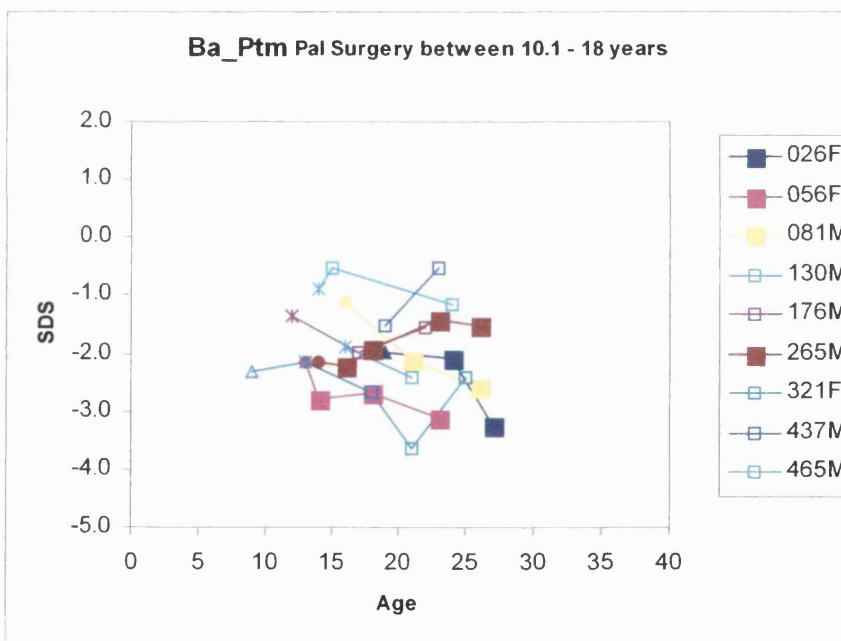
Fig. 5.3.25 PostPal Ba_Ptm - Maxillary Protrusion

Ba_Ptm Pal Surgery over 18.1 years

Legend:
- 042M
- 076M
- 132M
- 178F
- 371M

X-axis: Age
Y-axis: SDS
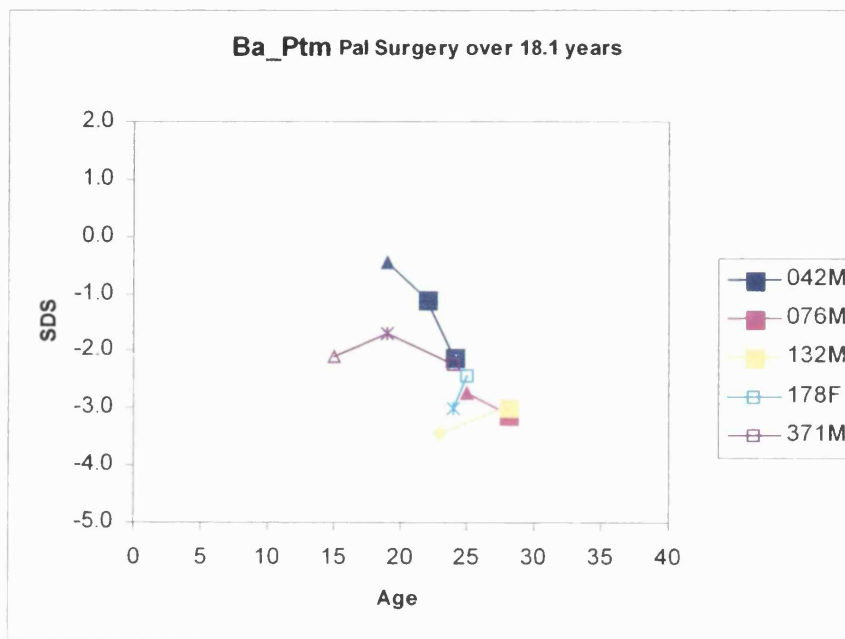
Statistical Analysis

Question	Coeff.	t ratio	P value
1	-1.63	-14.91	**0.0001**
2	0.11	5.47	**0.0001**
3	-0.01	-2.55	**0.013**

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2. Maxillary Protrusion

SNA   A decrease in the maxillary protrusion is noted. A significant negative growth coefficient over time after palatal repair is found, irrespective of the age of surgical intervention. Demonstrated by Subject 010M in Fig.5.3.6, Subject 022F in Fig.5.3.8 and Subject 042M in Fig.5.3.10.

SNANS   Statistically significant low mean SDS in the anterior nasal spine angle to the cranial base are observed. A significant increase in the acceleration of growth over time is noted. However, the final growth outcome remains significantly below the Control population values for SNANS. A reduction in the rate of growth is observed the later the palatal surgery is performed. Subject 030M in Fig.5.3.12 shows better growth potential than Subject 371M in Fig.5.3.15 but both subjects remained well below the Control population spread.

NSPTM   The relationship of PTM to the cranial base remained within the Control populations 95% confidence intervals.

Ba_PTM   The overall relationship of the posterior maxilla to the cranial base was significantly shorter. A statistically different increase in accelerated growth over time is noted, this reduces with delayed hard palate repair, the older the subject, less growth is attained.

In the Longitudinal study there were statistically different findings.

	Question	P Value	Description
SNA	2	***	Steep rate of fall with age
SNAS	2	***	Steep rate of fall with age
SNIS	1	***	Very low mean SDS
	2	***	Steep rate of fall with age
SNPr	1	***	Very low mean SDS
	2	***	Steep rate of fall with age
SNAns	1	***	Very low mean SDS
	2	***	Steep rate of rise with age
	3	***	Reduction in rate of rise with age at operation
NSPtm	1	***	Very low mean SDS
Ba_Ptm	1	***	Very low mean SDS
	2	***	Steep rate of rise with age
	3	*	Reduction in rate of rise with age at operation
Ar_Ptm	1	***	Very low mean SDS
	2	*	Rise with age

3. Facial Depth and Maxillary Length

Three variables were analysed: ANS_PTM   Ar_ANS   Ar_A

One variable will be presented   ANS_PTM.

Fig. 5.3.26 PostPal Ans_Ptm - Maxillary Length

Ans_Ptm Pal Surgery under 2.5 years

Legend: 010M, 106F, 168M, 179F, 302M, 491F

Fig. 5.3.27 PostPal Ans_Ptm - Maxillary Length

Ans_Ptm Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F

197
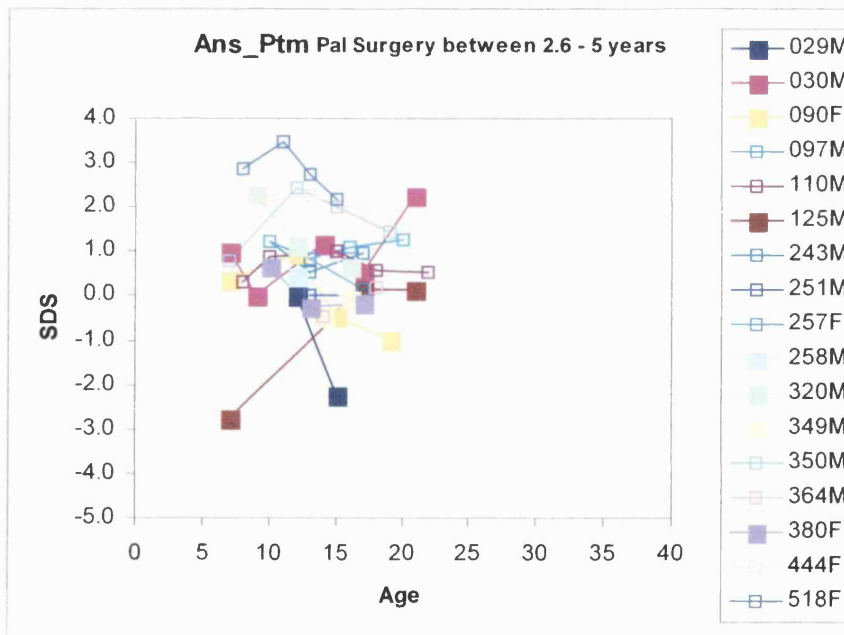
Fig. 5.3.28 PostPal Ans_Ptm - Maxillary Length

Ans_Ptm Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
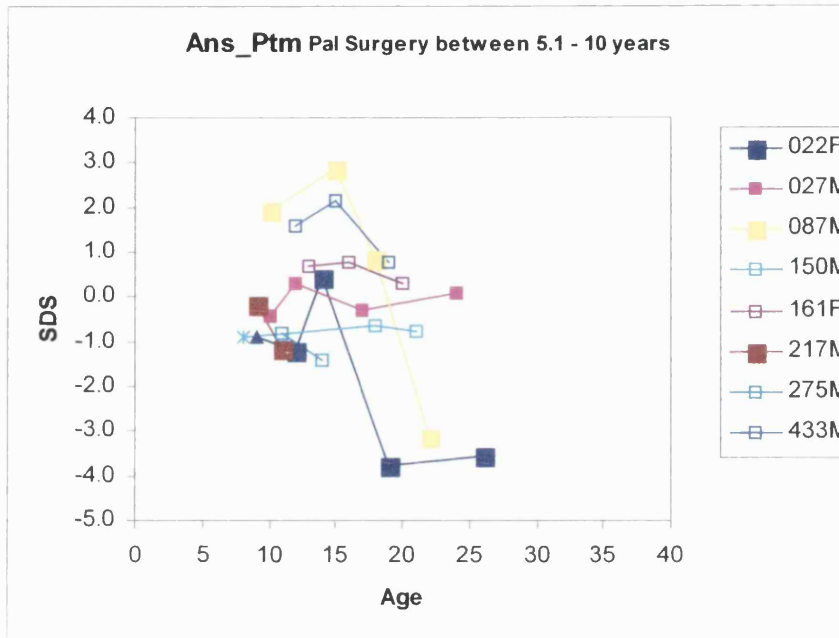
Fig. 5.3.29 PostPal Ans_Ptm - Maxillary Length

Ans_Ptm Pal Surgery between 10.1 - 18 years

Legend: 056F, 081M, 176M, 265M, 321F, 437M, 465M
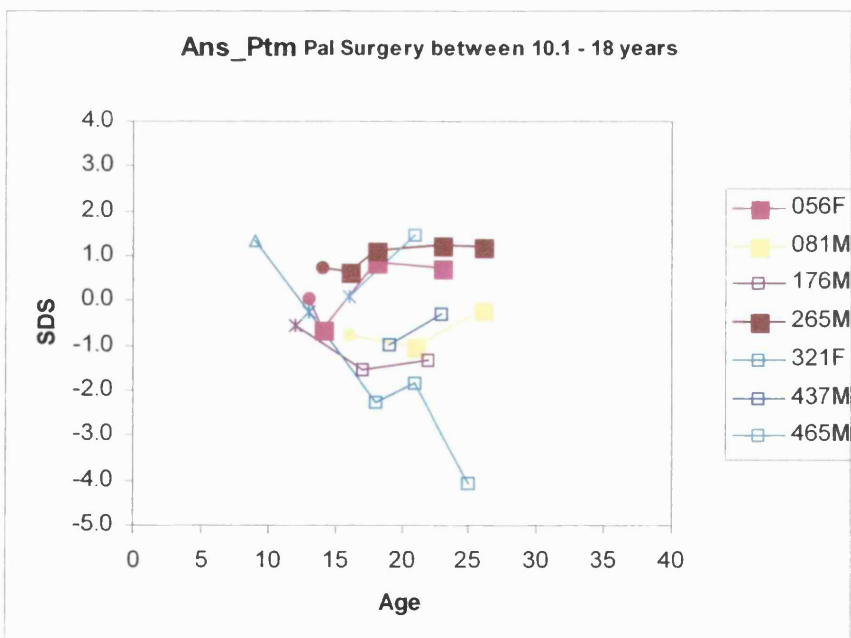
Fig. 5.3.30 PostPal Ans_Ptm - Maxillary Length

Ans_Ptm Pal Surgery over 18.1 years

Legend: 042M, 076M, 132M, 178F, 371M

Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.32	2.39	**0.02**
2	-0.05	0.02	**0.03**
3	-0.005	-0.69	0.49

3. Maxillary Length

The initial protrusion of the premaxillary segment becomes retroclined after lip and palate surgery. A significantly high overall mean value increase in maxillary length is noted. The initial overgrowth in maxillary length is reduced after lip repair and continues to reduce post palatal repair. The palatal length outcome, after lip and palate surgery, remains within the Control 95% confidence intervals. The initial overgrowth is reduced to a normal non-cleft palatal length. An extreme example of this is seen in Subject 371M in Fig.5.3.30.

In the Longitudinal study there were statistically different findings between the PostPal groups and the Control population.

	Question	P Value	Description
Ans_Ptm	1	*	High mean SDS
	2	*	Negative growth coefficient with age
Ar_Ans	1	*	High mean SDS
Ar_A			Nothing statistically significant.

4. Maxillary / Mandibular Protrusion

ANB No data available

No data is available for the variable ANB. Conversion of the variable measures into SDS was inaccurate due to both positive and negative values. Maxillary / Mandibular protrusion will be examined by the convexity angle NaPg.

One variable was analysed NAPg

Fig. 5.3.31 PostPal NaPg Maxillary/Mandibular Protrusion

NAPg Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
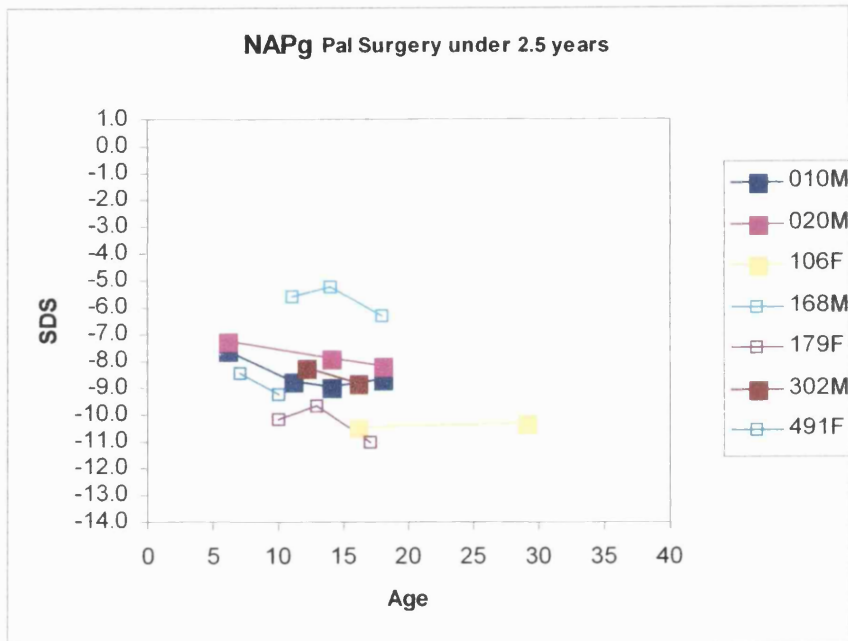
Fig. 5.3.32 PostPal NaPg Maxillary/Mandibular Protrusion

NAPg Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F
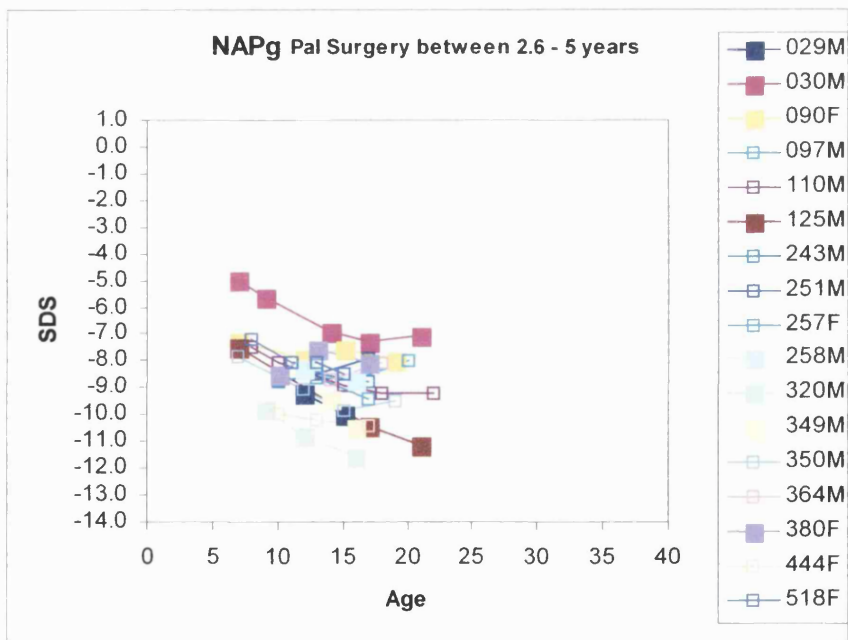
Fig. 5.3.33 PostPal NaPg Maxillary/Mandibular Protrusion

NAPg Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
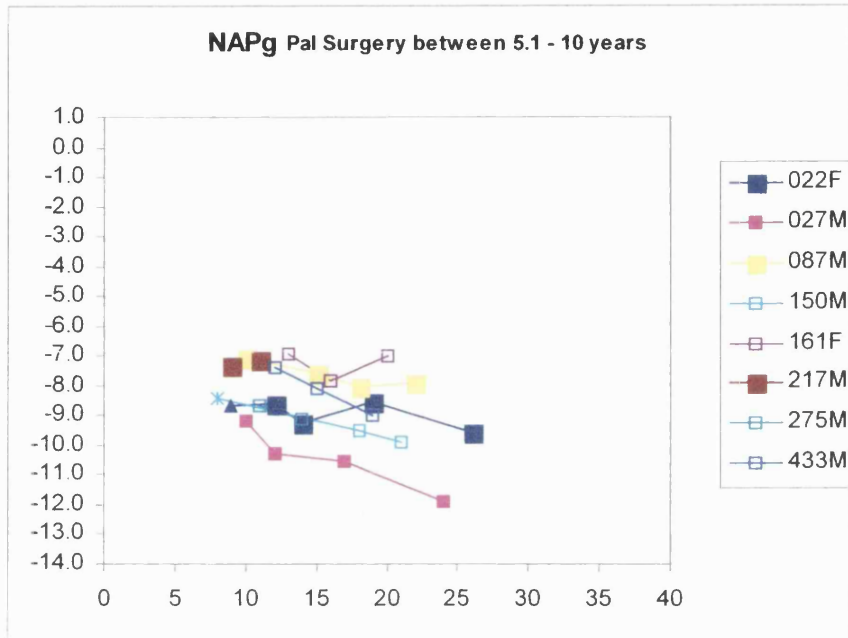
Fig. 5.3.34 PostPal NaPg Maxillary/Mandibular Protrusion

NAPg Pal Surgery between 10.1 - 18 years

Legend: 026F, 056F, 081M, 130M, 176M, 265M, 321F, 437M, 465M
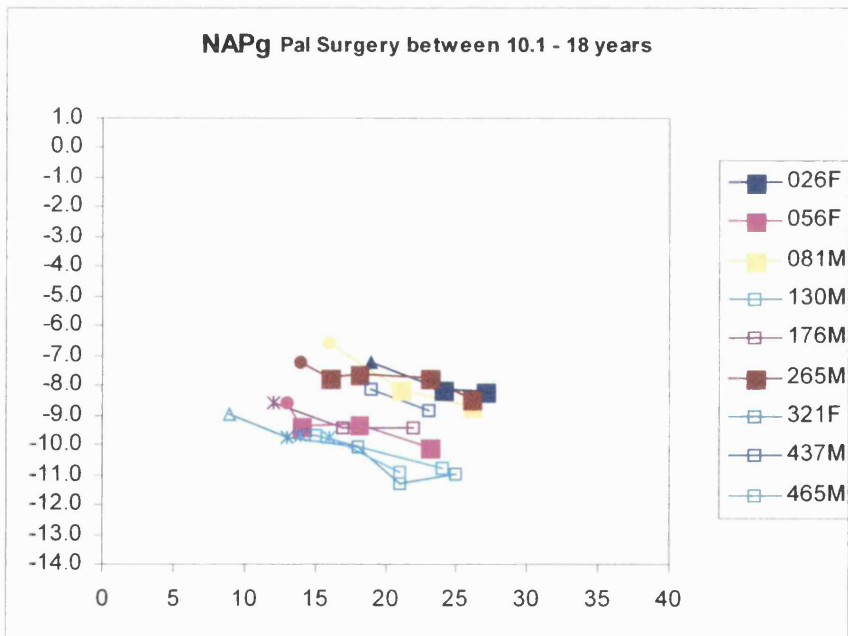
Fig. 5.3.35 PostPal NaPg Maxillary/Mandibular Protrusion

NAPg Pal Surgery over 18.1 years

[Chart: SDS (y-axis, from 1.0 to -14.0) versus Age (x-axis, 0 to 40), with data series 042M, 076M, 132M, 178F, 371M]
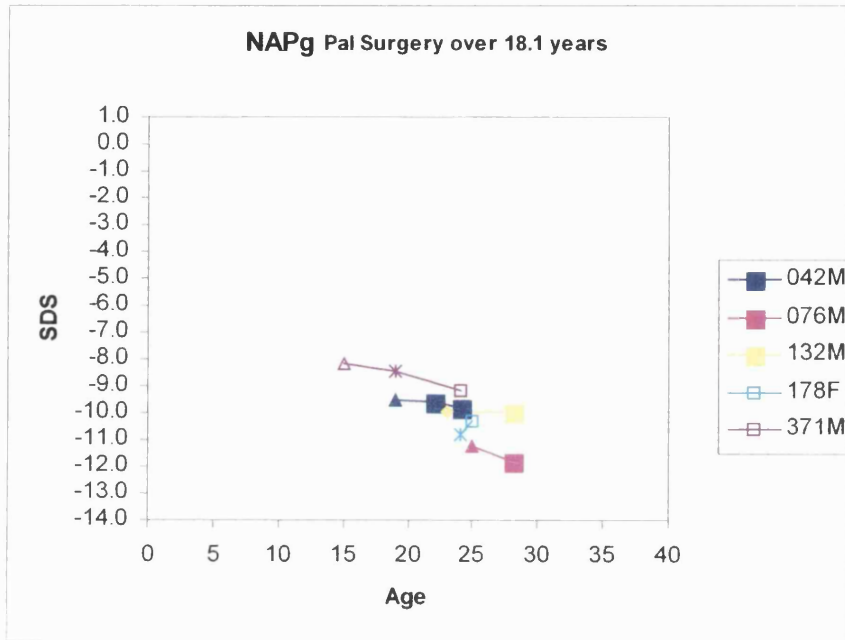
Statistical Analysis

Question	Coeff.	t ratio	P value
1	-8.73	-76.18	**0.0001**
2	-0.12	-10.09	**0.0001**
3	-0.0003	-0.08	0.94

4. Maxillary/Mandibular Protrusion

Statistically low overall mean SDS was observed. Further reduction is observed over time, the angle significantly decreases, as the subject grows older; as demonstrated by Subject 027M in Fig.5.3.33.

In the Longitudinal study there were statistically different findings between the PostPal groups and the Control population.

	Question	P Value	Description
NAPg	1	***	Very low mean SDS
	2	***	Steep fall in rate with age

5. Mandibular Protrusion

The following four variables were analysed: SNII   SNID   SNB   SNPg

One variable will be presented SNB

Fig. 5.3.36 PostPal SNB - Mandibular Protrusion

SNB Pal Surgery under 2.5 years

Fig. 5.3.37 PostPal SNB - Mandibular Protrusion

SNB Pal Surgery between 2.6 - 5 years
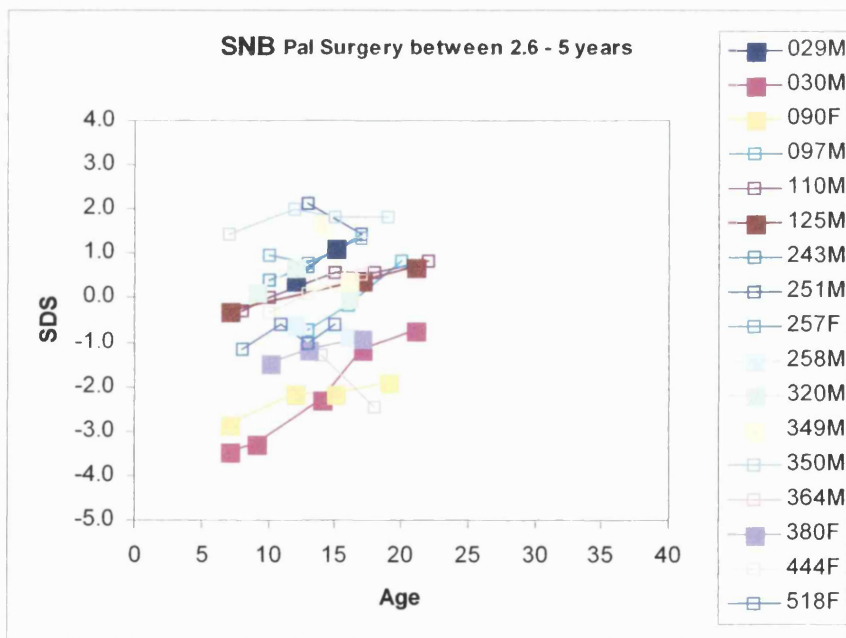
Fig. 5.3.38 PostPal SNB - Mandibular Protrusion

SNB Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
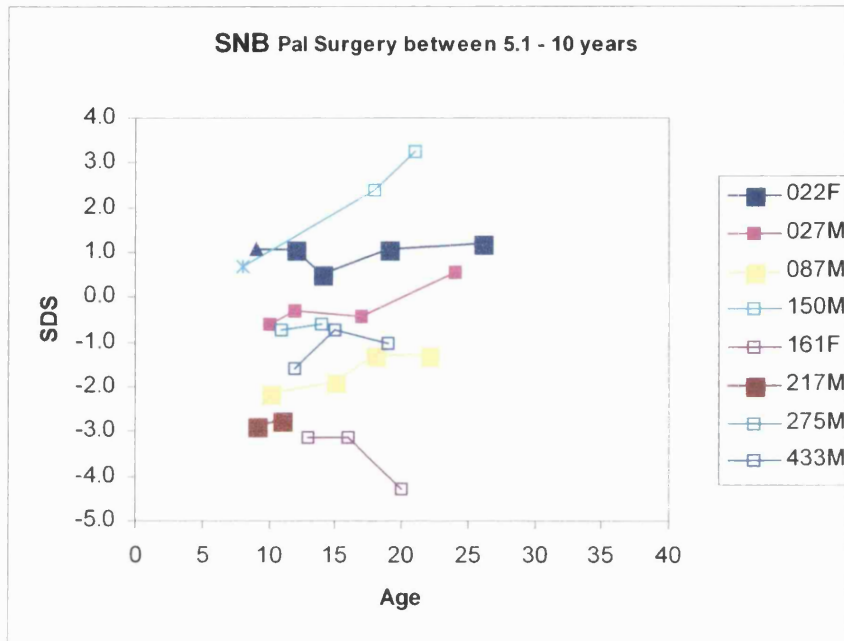
Fig. 5.3.39 PostPal SNB - Mandibular Protrusion

SNB Pal Surgery between 10.1 - 18 years

Legend: 026F, 056F, 081M, 130M, 176M, 265M, 321F, 437M, 465M
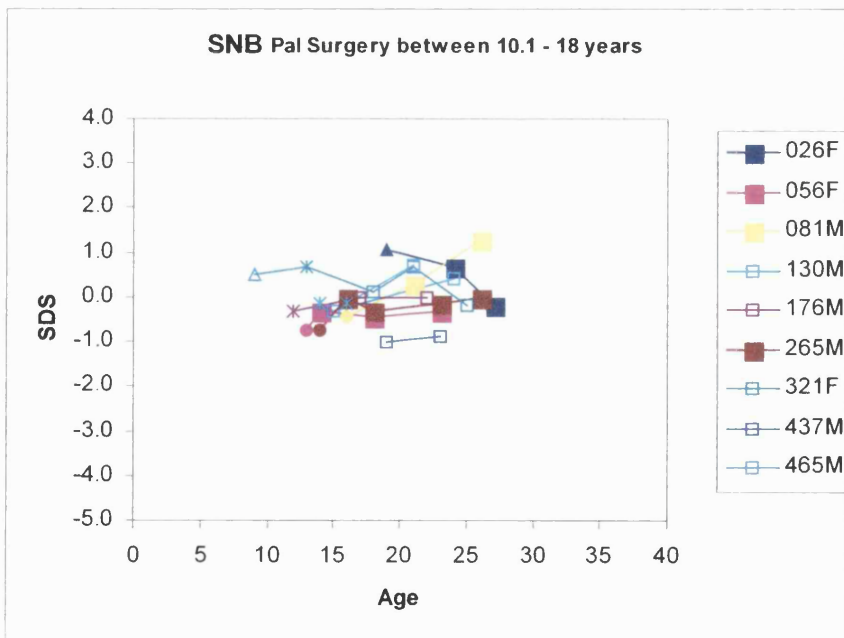
Fig. 5.3.40 PostPal SNB - Mandibular Protrusion

SNB Pal Surgery over 18.1 years
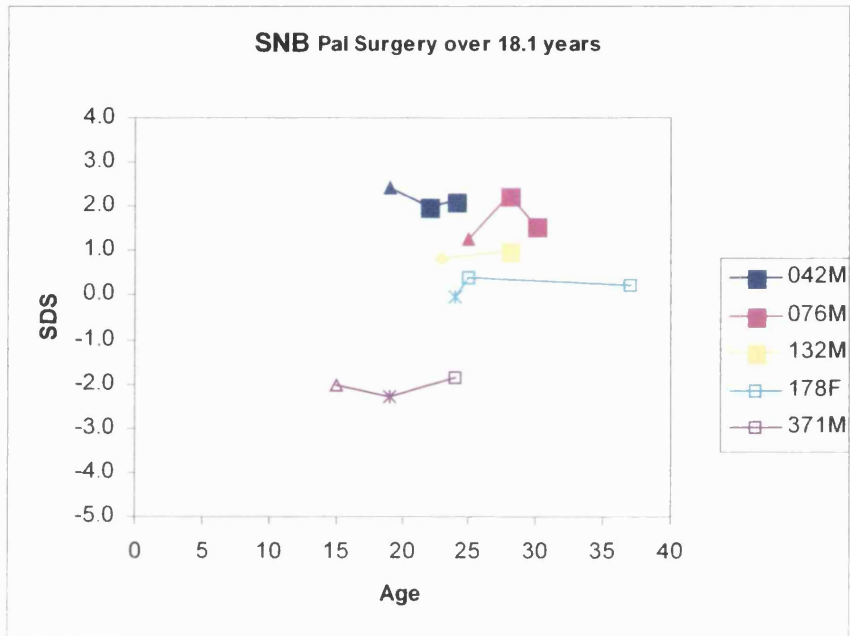
Statistical Analysis

Question	Coeff.	t ratio	P value
1	-0.19	-1.59	0.11
2	0.07	6.16	**0.0001**
3	-0.007	-2.52	**0.01**

5. Mandibular Protrusion

The overall mean values for mandibular protrusion were within the Control 95% confidence limits. Some low values are noted but these were not found to be statistically significant. However, a statistically different increase in acceleration of growth was observed. This rate of growth reduced with the age at palatal surgery. The older the subject is at surgical intervention the less growth potential available.

In the Longitudinal study there were statistically different findings between the PostPal groups and the Control population.

	Question	P Value	Description
SNII	1	***	Very wide distribution at start of treatment
	2	***	Fall with age
SNID	1	*	Low mean SDS
	2	***	Steep rise with age
	3	**	Reduction in rate of rise with age at operation
SNB	2	***	Steep rise with age
	3	*	Reduction in rate of rise with age at operation
SNPg	2	***	Steep rise with age
	3	*	Reduction in rate of rise with age at operation

6. Mandibular Dimensions

Five variables were analysed:

Ar_TGO   TGO_Gn   ArTGOGn   Ar_Pg   Ar_B

Four variables will be presented: Ar_TGO   TGO_Gn   ArTGOGn   Ar_Pg

Fig. 5.3.41 PostPal Ar_TGO - Ramus Length

Ar_TGO Pal Surgery under 2.5 years
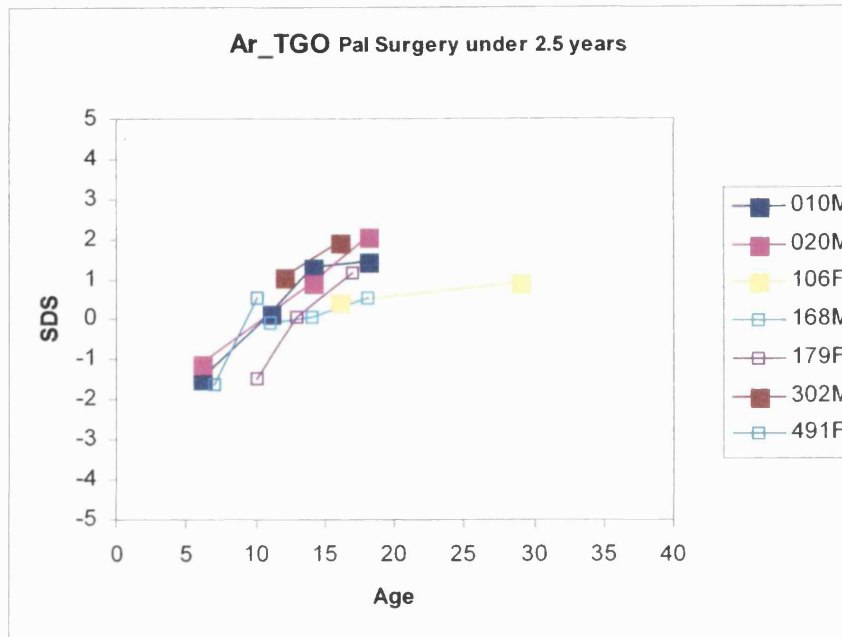
Fig. 5.3.42 PostPal Ar_TGO - Ramus Length

Ar_TGO Pal Surgery between 2.6 - 5 years
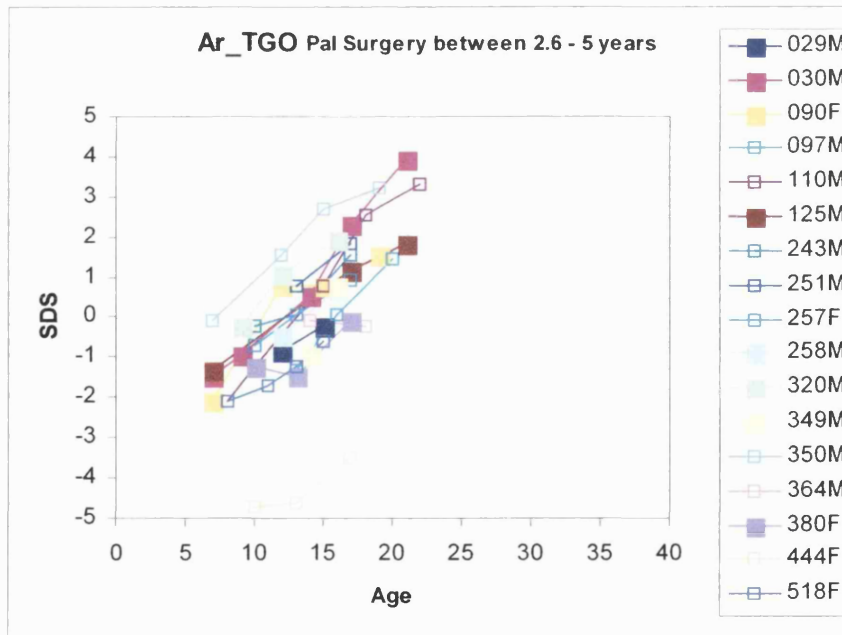
Fig. 5.3.43 PostPal Ar_TGO - Ramus Length

Ar_TGO Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
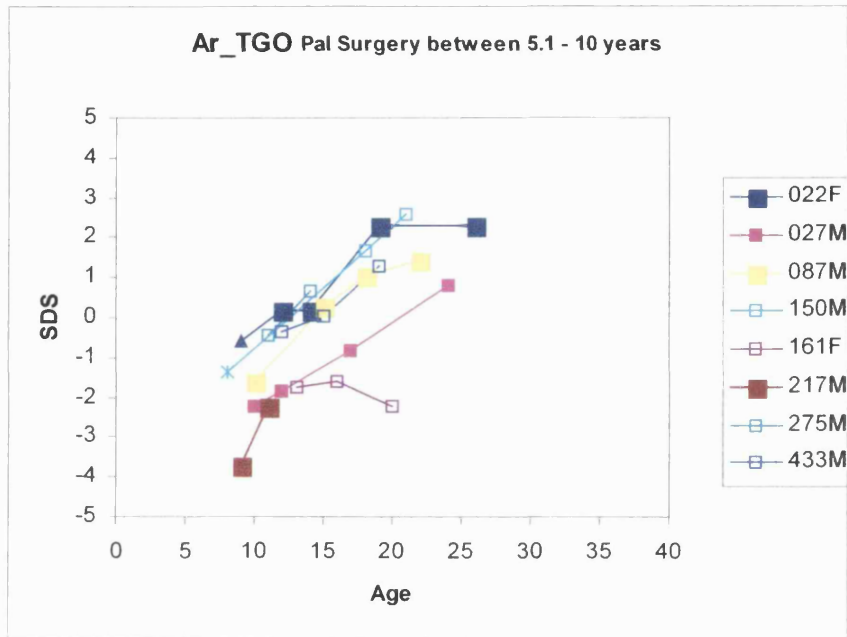
Fig. 5.3.44 PostPal Ar_TGO - Ramus Length

Ar_TGO Pal Surgery between 10.1 - 18 years

Legend: 026F, 056F, 081M, 130M, 176M, 265M, 321F, 437M, 465M
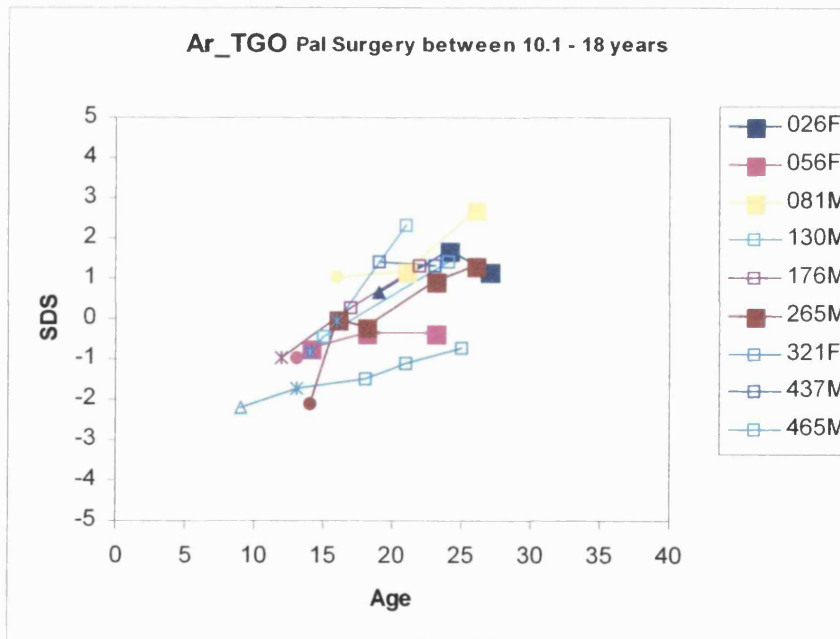
Fig. 5.3.45 PostPal Ar_TGO - Ramus Length

Ar_TGO Pal Surgery over 18.1 years

Legend:
- 042M
- 076M
- 132M
- 178F
- 371M
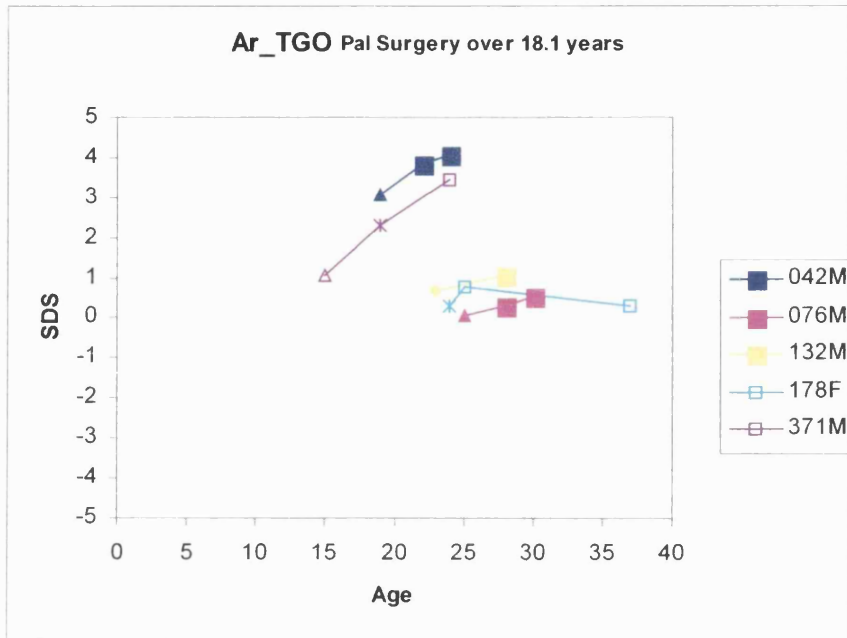
Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.29	2.06	**0.04**
2	0.24	17.58	**0.0001**
3	-0.01	-2.93	**0.005**

Fig. 5.3.46 PostPal TGO_Gn - Mandibular Length

TGO_Gn Pal Surgery under 2.5 years
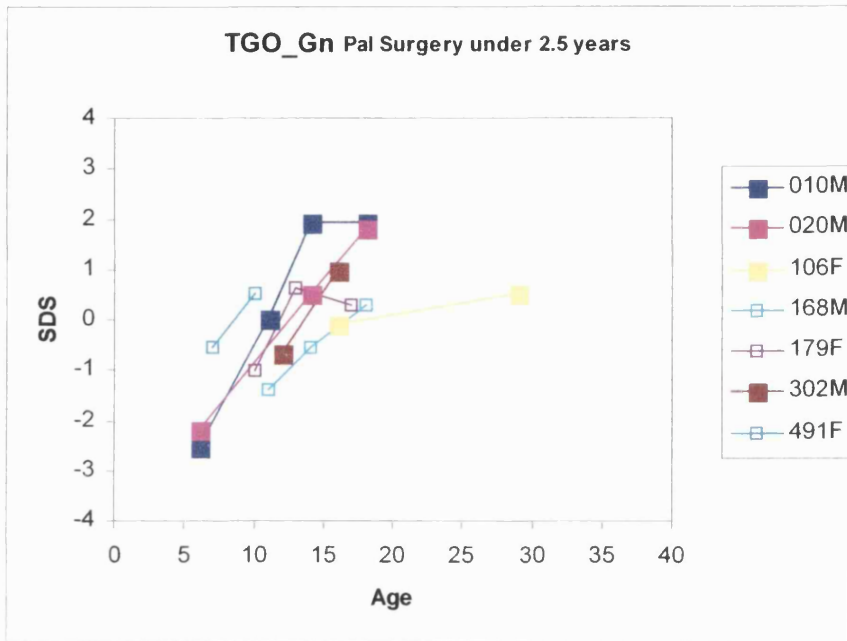
Fig. 5.3.47 PostPal TGO_Gn - Mandibular Length

TGO_Gn Pal Surgery between 2.6 - 5 years

Fig. 5.3.48 PostPal TGO_Gn - Mandibular Length

TGO_Gn Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
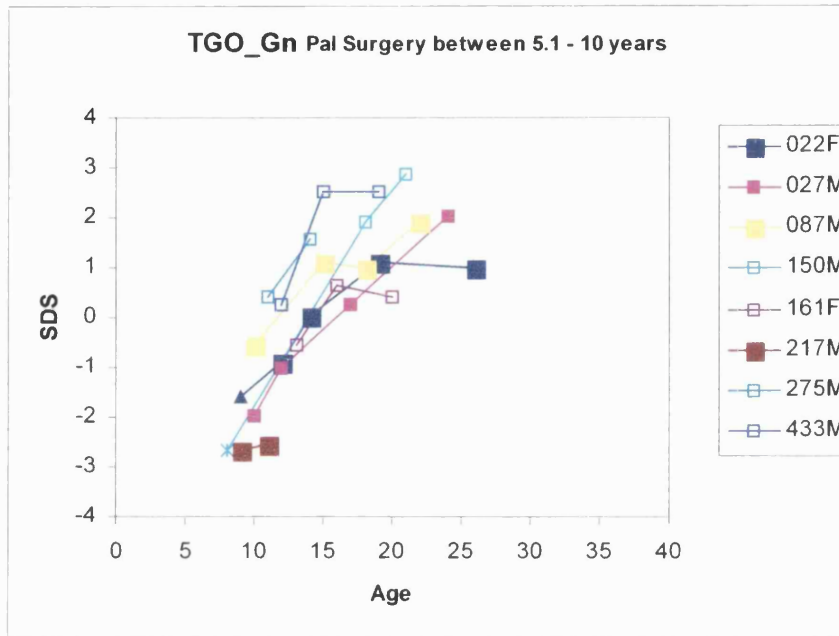
Fig. 5.3.49 PostPal TGO_Gn - Mandibular Length

TGO_Gn Pal Surgery between 10.1 - 18 years

Legend: 026F, 056F, 081M, 130M, 176M, 265M, 321F, 437M, 465M

Fig. 5.3.50 PostPal TGO_Gn - Mandibular Length

TGO_Gn Pal Surgery over 18.1 years
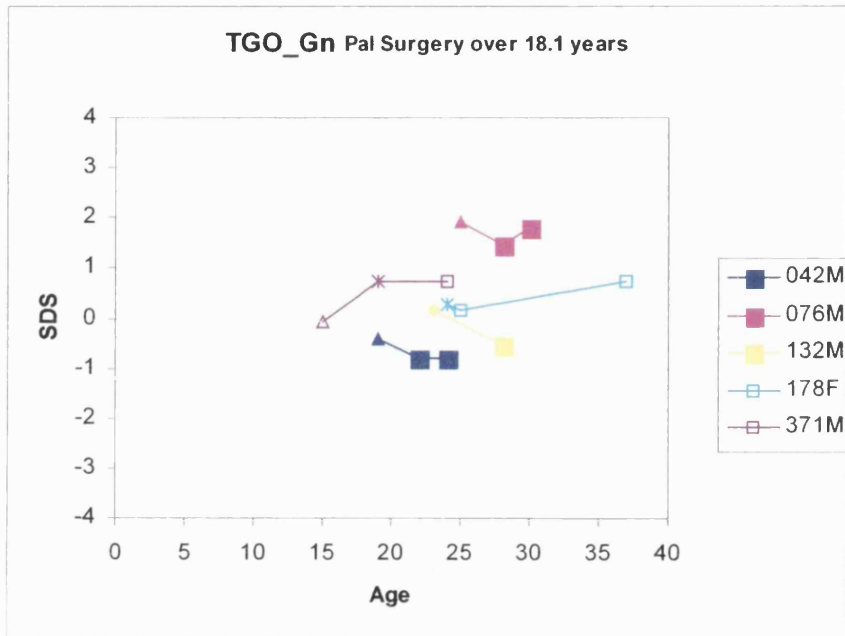
Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.52	3.91	**0.0001**
2	0.27	15.02	**0.0001**
3	-0.02	-3.42	**0.001**

Fig. 5.3.51 PostPal ArTGOGn - Gonial Angle

ArTGOGn Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
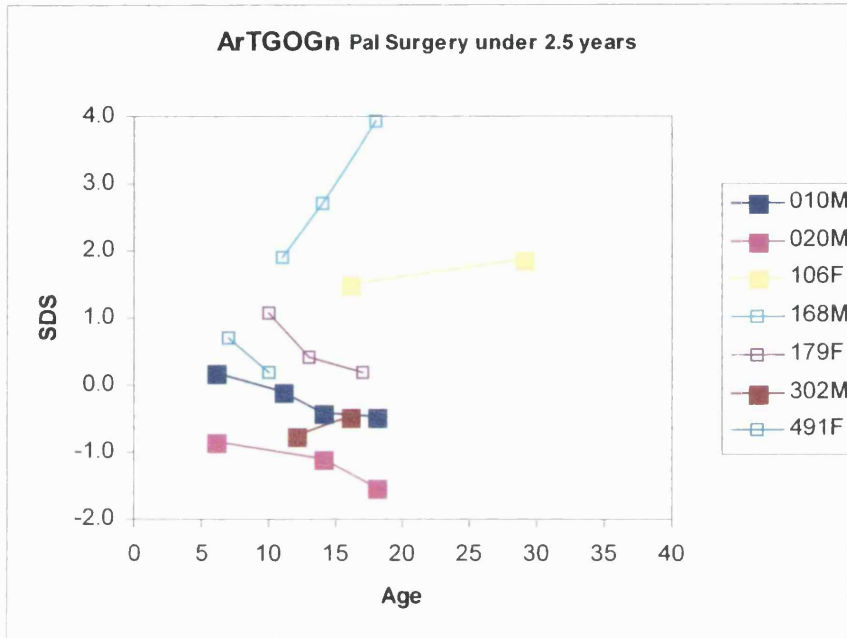
Fig. 5.3.52 PostPal ArTGOGn - Gonial Angle

ArTGOGn Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F
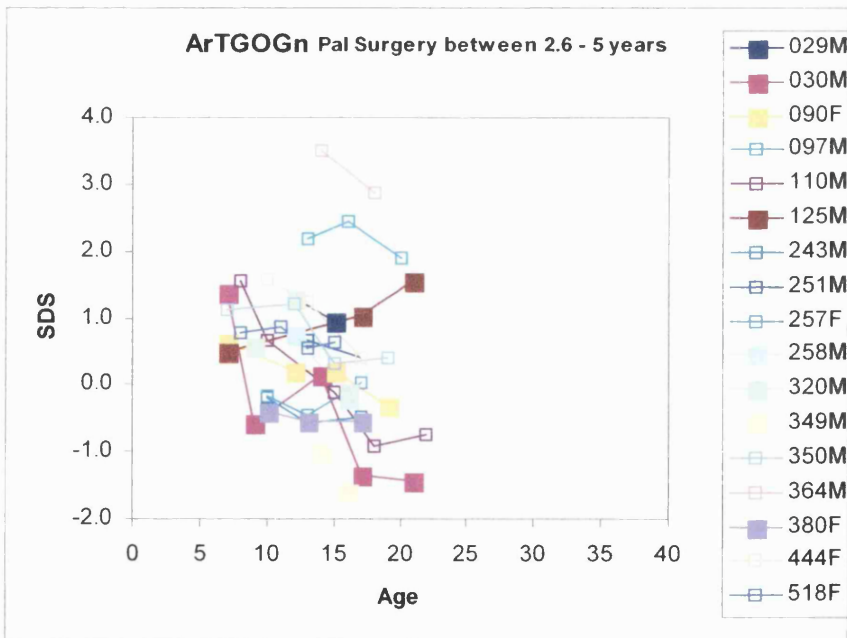
Fig. 5.3.53 PostPal ArTGOGn - Gonial Angle

ArTGOGn Pal Surgery between 5.1 - 10 years
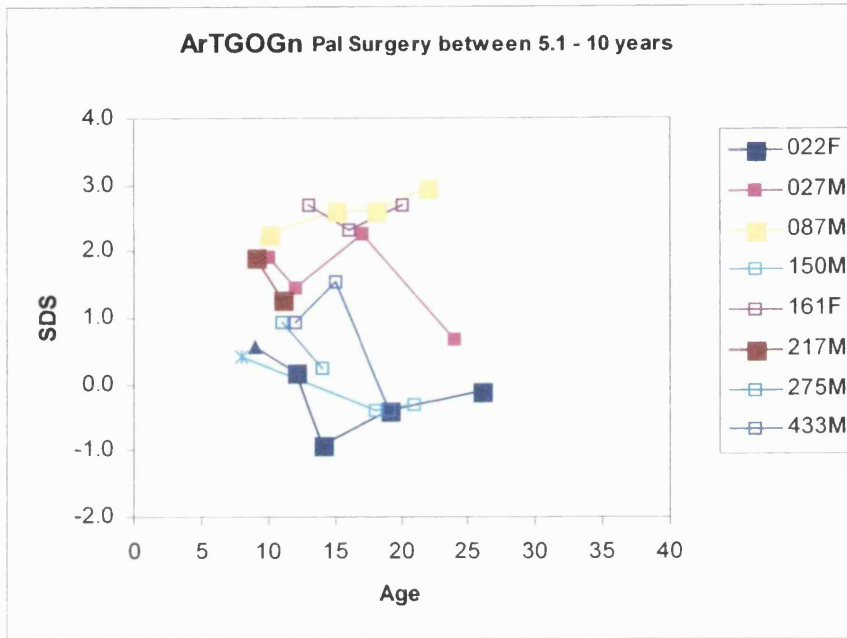
Fig. 5.3.54 PostPal ArTGOGn - Gonial Angle

ArTGOGn Pal Surgery between 10.1 - 18 years
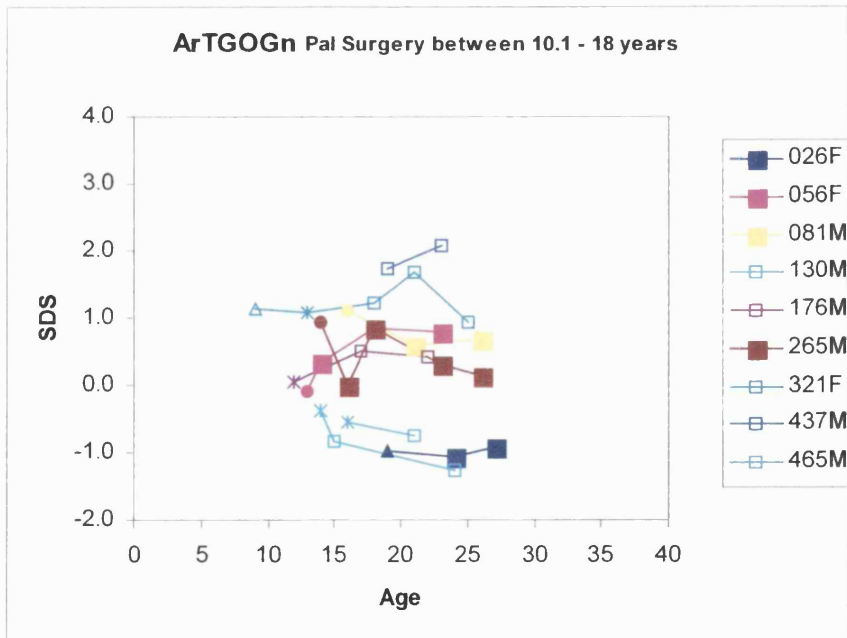
Fig. 5.3.55 PostPal ArTGOGn - Gonial Angle

ArTGOGn Pal Surgery over 18.1 years
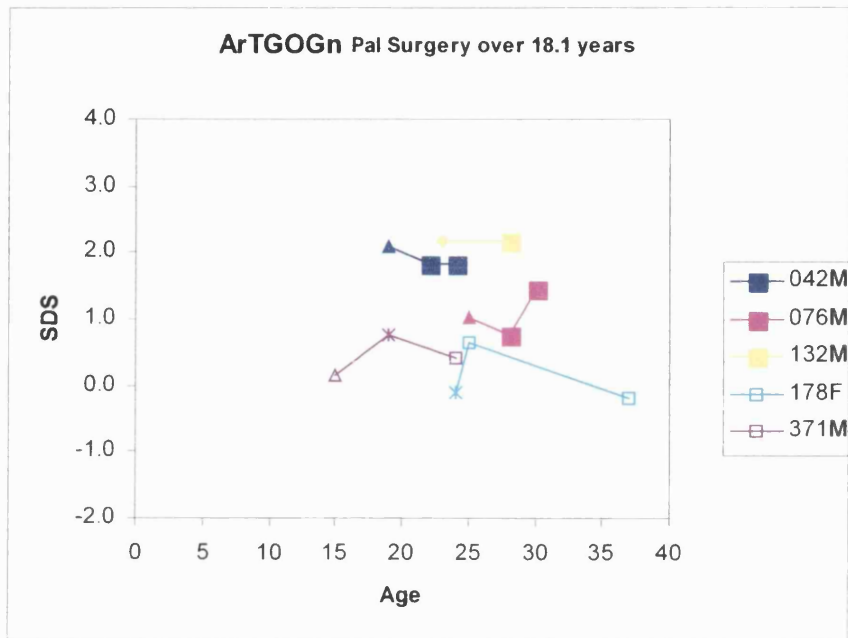
Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.62	6.05	**0.0001**
2	-0.05	-3.71	**0.0004**
3	0.003	0.81	0.42

Fig. 5.3.56 PostPal Ar_Pg - Mandibular Length

Ar_Pg Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
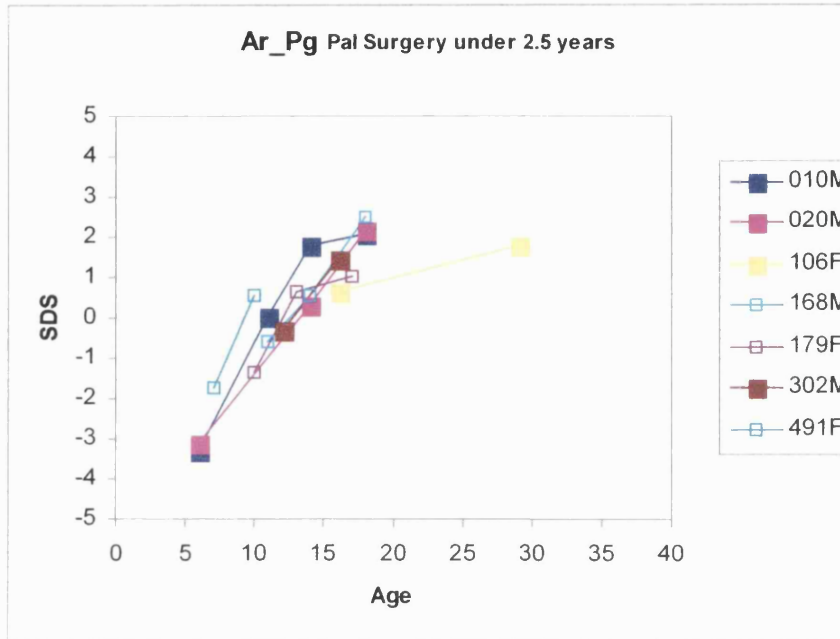
Fig. 5.3.57 PostPal Ar_Pg - Mandibular Length

Ar_Pg Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F
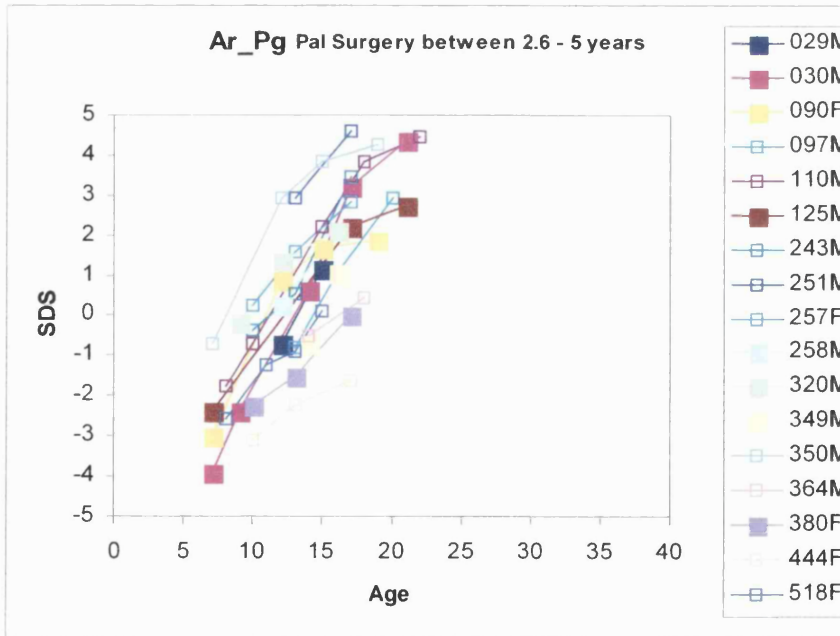
Fig. 5.3.58 PostPal Ar_Pg - Mandibular Length

Ar_Pg Pal Surgery between 5.1 - 10 years

Legend:
- 022F
- 027M
- 087M
- 150M
- 161F
- 217M
- 275M
- 433M
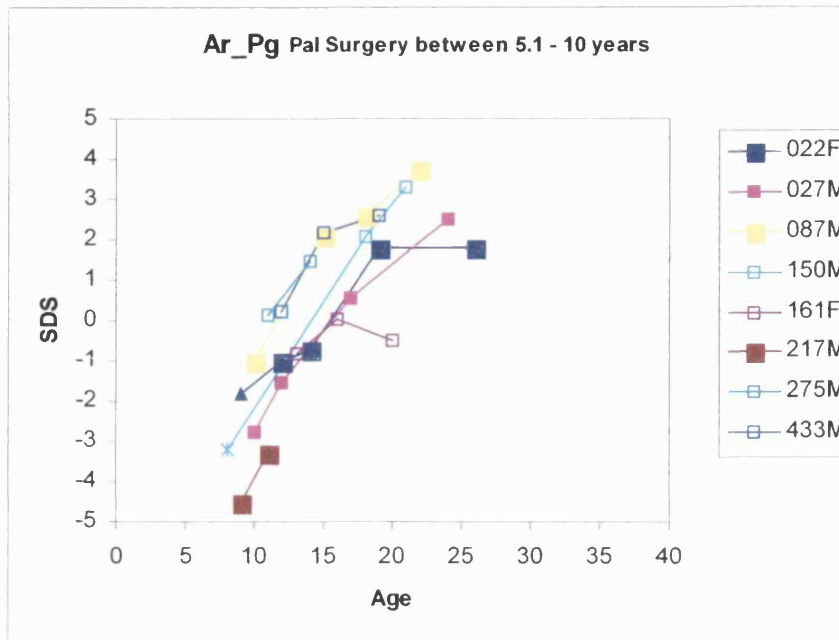
Fig. 5.3.59 PostPal Ar_Pg - Mandibular Length

Ar_Pg Pal Surgery between 10.1 - 18 years

Legend:
- 026F
- 056F
- 081M
- 130M
- 176M
- 265M
- 321F
- 437M
- 465M
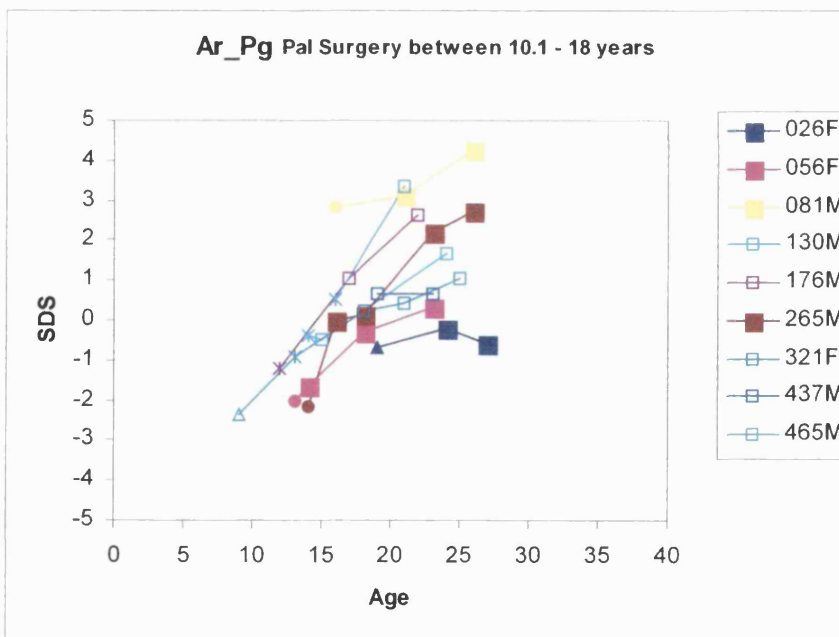
Fig. 5.3.60 PostPal Ar_Pg - Mandibular Length
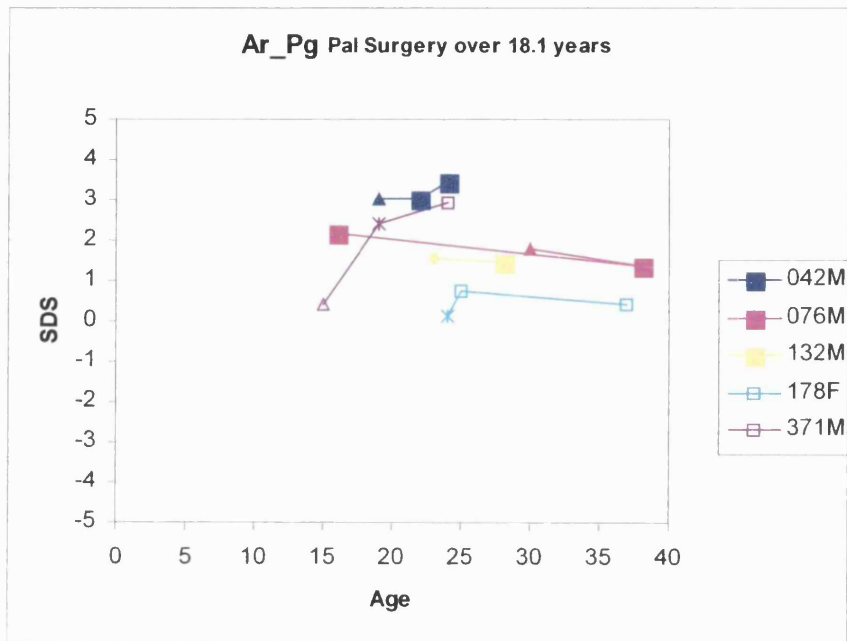
Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.69	3.95	**0.0001**
2	0.38	19.95	**0.0001**
3	-0.02	-4.45	**0.0001**

6. Mandibular Dimensions

Ar_TGO, TGO_Gn   & Ar_Pg   Statistically low mean overall SDS are observed in all three of the linear variables presented in these results. A steep increase in growth acceleration is noted with age. The length starts shorter than the Control population values but after palate surgery, the subsequent significant increase in accelerated growth results in an overgrowth in the mandibular dimensions. However, this rate of growth diminishes the older the subject is at palate repair. Subject 030M in Fig.5.3.57 demonstrates a higher rate of growth than Subject 132M in Fig.5.3.60.

ArTGOGn   A significantly more obtuse Gonial angle is observed in the BCLP PostPal subjects than in the Control population. The Gonial angle reduces significantly, with a negative growth coefficient over time; resulting in a normal Gonial angle in relation to the Control population.

In the Longitudinal study there were statistically different findings between the PostPal groups and the Control population.

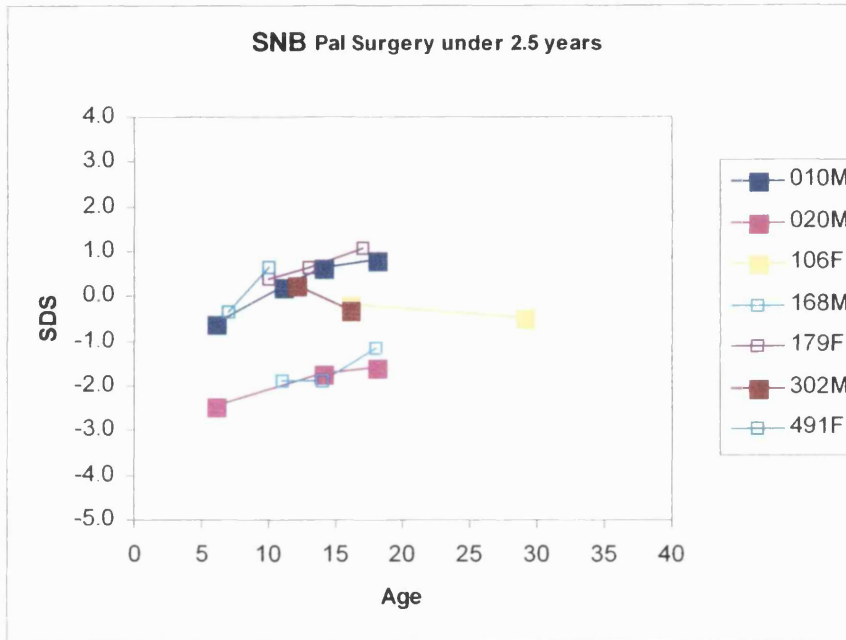|	Question	P Value	Description
Ar_TGO	1	*	Low mean SDS
	2	***	Steep rise with age
	3	**	Reduction in rate of rise with age at operation
TGO_Gn	1	***	Very low mean SDS
	2	***	Steep rise with age
	3	**	Reduction in rate of rise with age at operation
ArTGOGn	1	***	High mean SDS
	2	***	Fall with age
Ar_Pg	1	***	Very low mean SDS
	2	***	Steep rise with age
	3	***	Reduction in rate of rise with age at operation
Ar_B	1	*	Low mean SDS
	2	***	Steep rise with age
	3	***	Reduction in rate of rise with age at operation

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7. Facial Heights (Perpendicular distance)

Six variables were analysed:

S_N_ANS   TGO_Gn_ANS   PTM_ANS_Gn   N_S_PTM   N_S_TGO

S_N_Gn

Four variables will be presented:

S_N_ANS, N_S_PTM, N_S_TGO, S_N_Gn

Fig. 5.3.61 PostPal S_N_Ans - Upper Anterior Facial Height

S_N_Ans Pal Surgery under 2.5 years

Legend: 010M, 020M, 168M, 179F, 302M, 491F
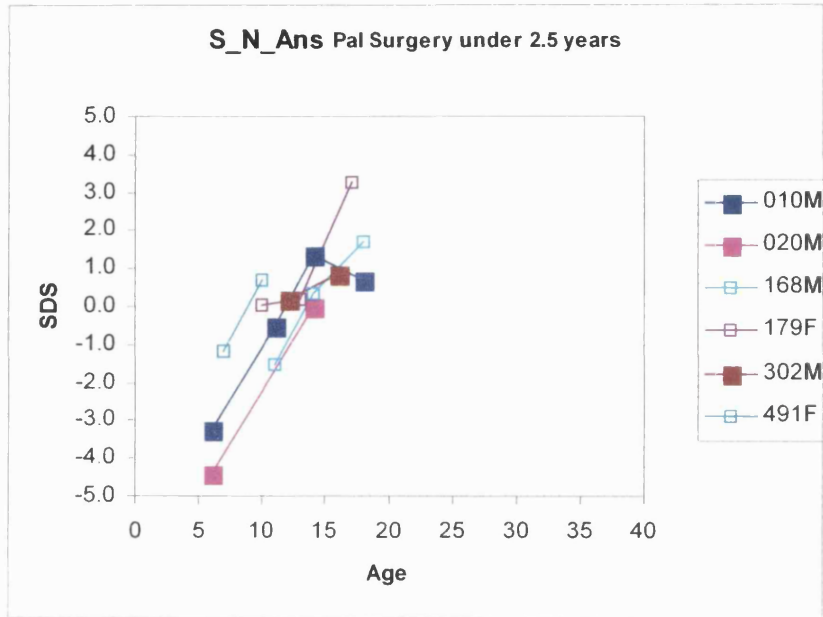
Fig. 5.3.62 PostPal S_N_Ans - Upper Anterior Facial Height

S_N_Ans Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F

Fig. 5.3.63 PostPal S_N_Ans - Upper Anterior Facial Height
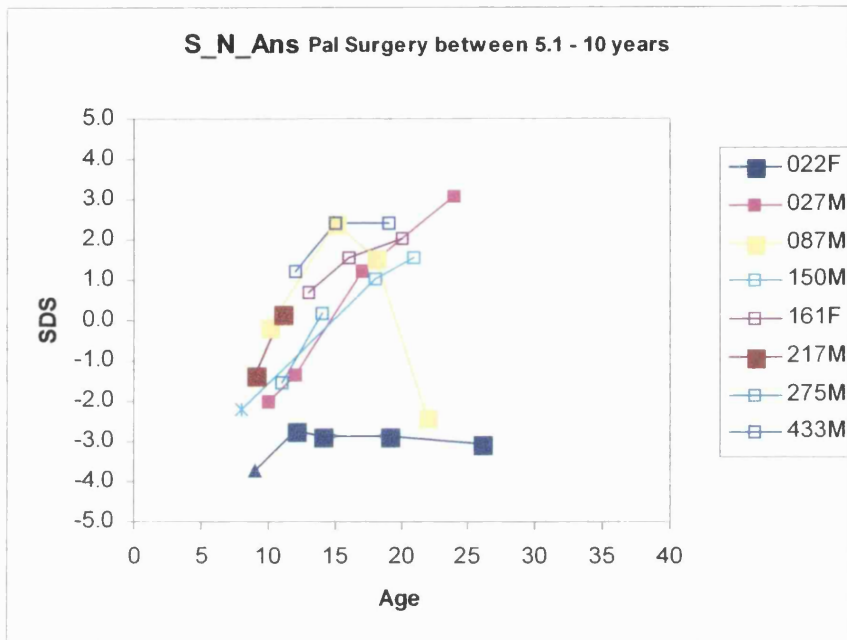
Fig. 5.3.64 PostPal S_N_Ans - Upper Anterior Facial Height
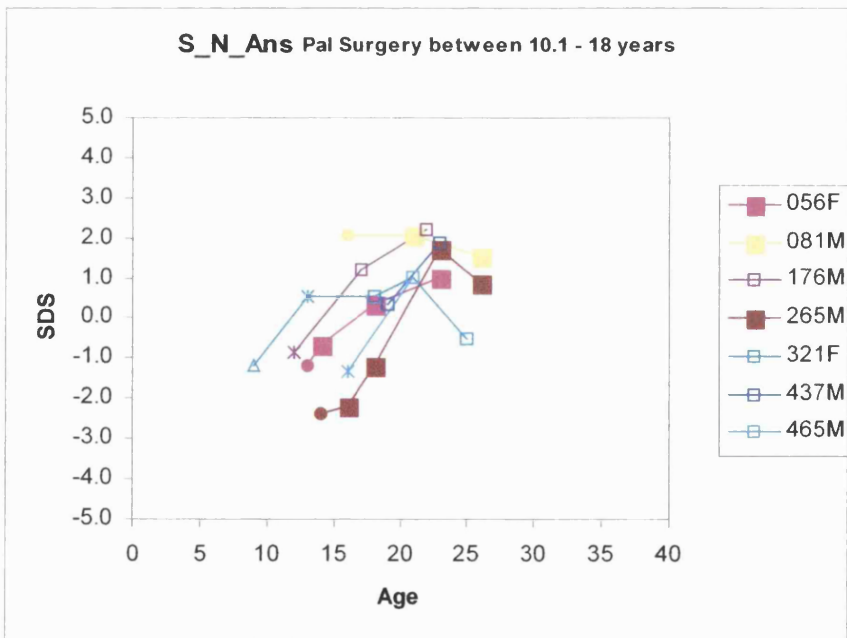
Fig. 5.3.65 PostPal S_N_Ans - Upper Anterior Facial Height
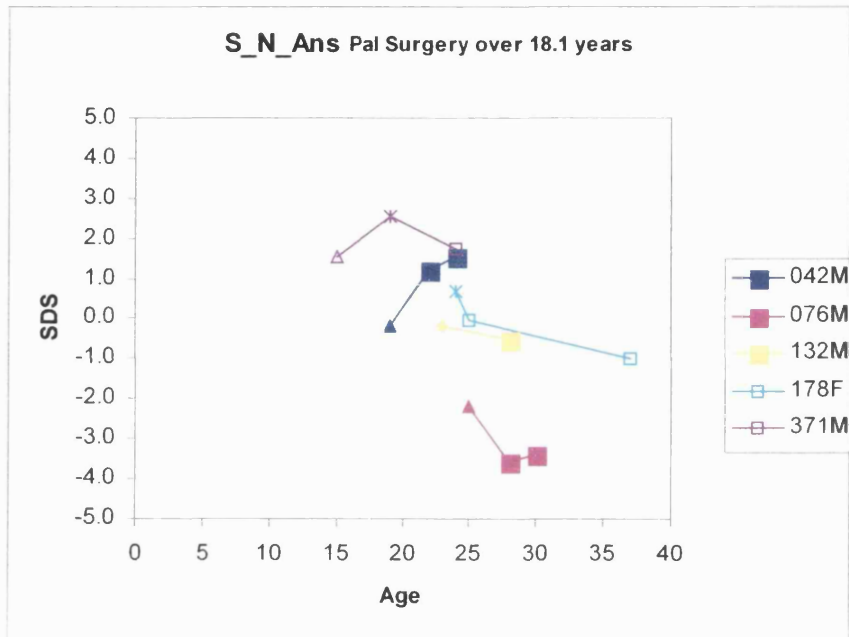
Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.27	1.63	0.11
2	0.25	8.31	**0.0001**
3	-0.02	-2.27	**0.03**

Fig. 5.3.66 PostPal N_S_Ptm - Upper Posterior Facial Height

N_S_Ptm Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
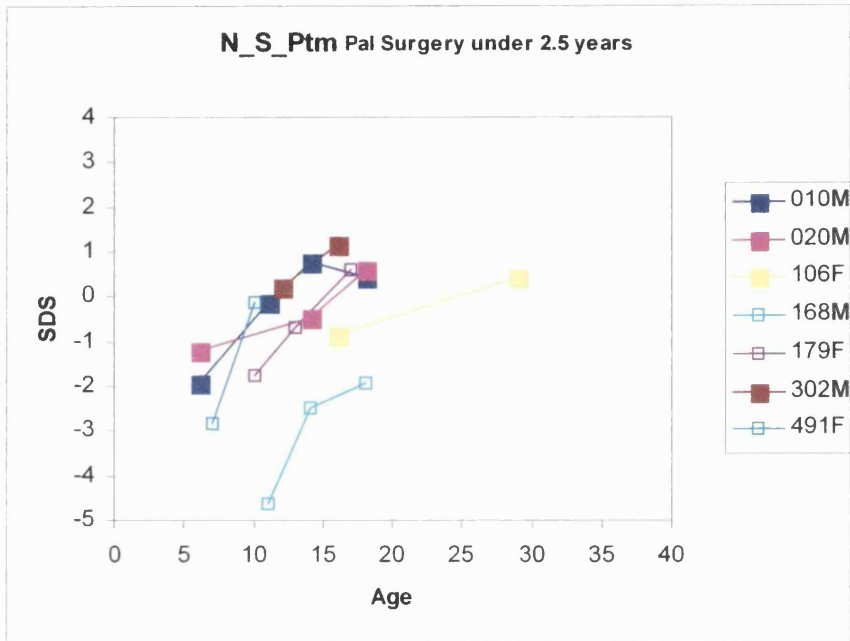
Fig. 5.3.67 PostPal N_S_Ptm - Upper Posterior Facial Height

N_S_Ptm Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F
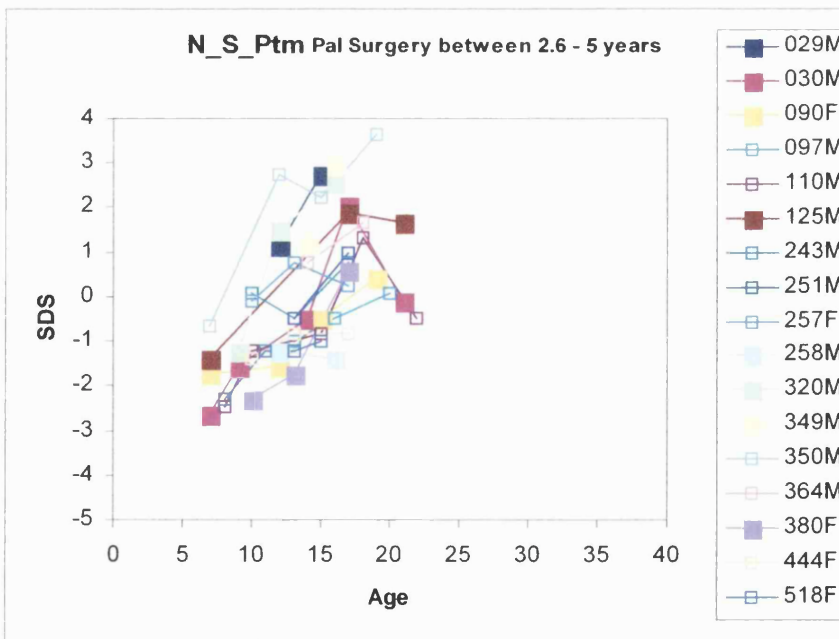
Fig. 5.3.68 PostPal N_S_Ptm - Upper Posterior Facial Height

N_S_Ptm Pal Surgery between 5.1 - 10 years
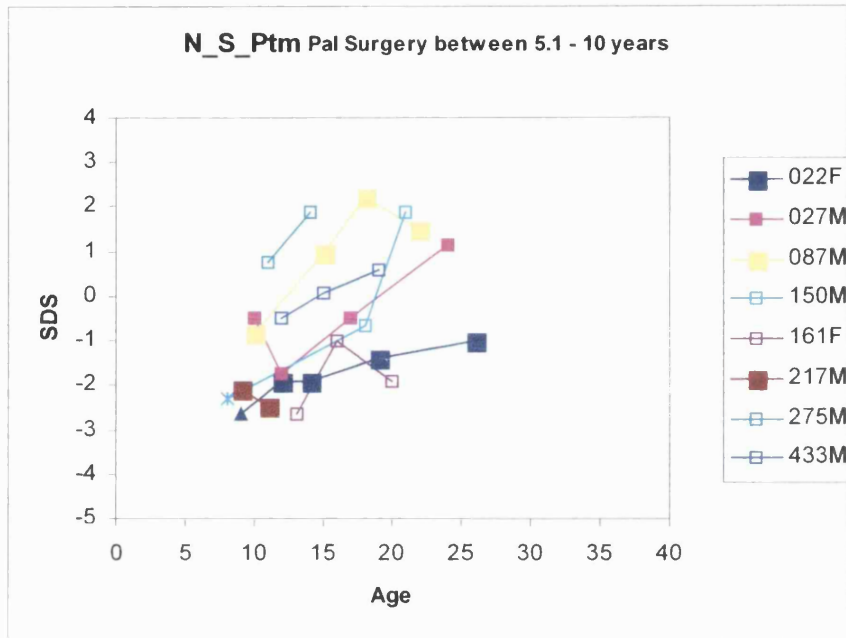
Fig. 5.3.69 PostPal N_S_Ptm - Upper Posterior Facial Height

N_S_Ptm Pal Surgery between 10.1 - 18 years
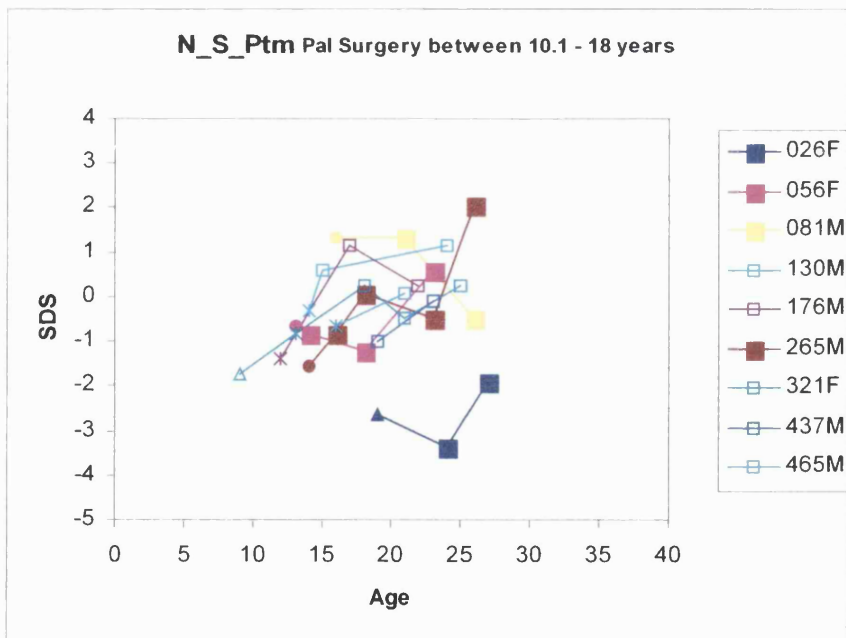
Fig. 5.3.70 PostPal N_S_Ptm - Upper Posterior Facial Height

N_S_Ptm Pal Surgery over 18.1 years
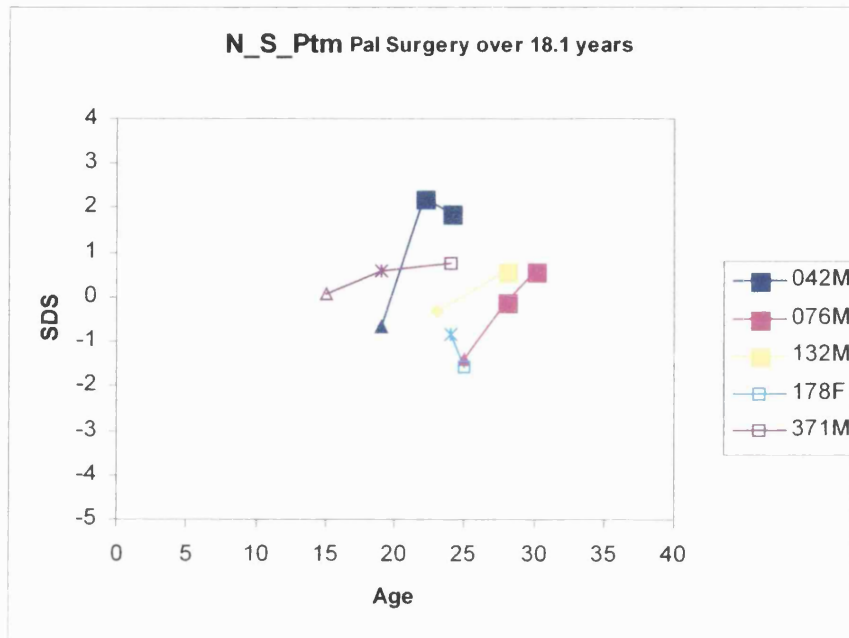
Statistical Analysis

Question	Coeff.	t ratio	P value
1	-0.21	-1.60	0.11
2	0.18	8.56	**0.0001**
3	-0.01	-2.27	**0.03**

Fig. 5.3.71 PostPal N_S_TGO - Total Posterior Facial Height

N_S_TGO Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
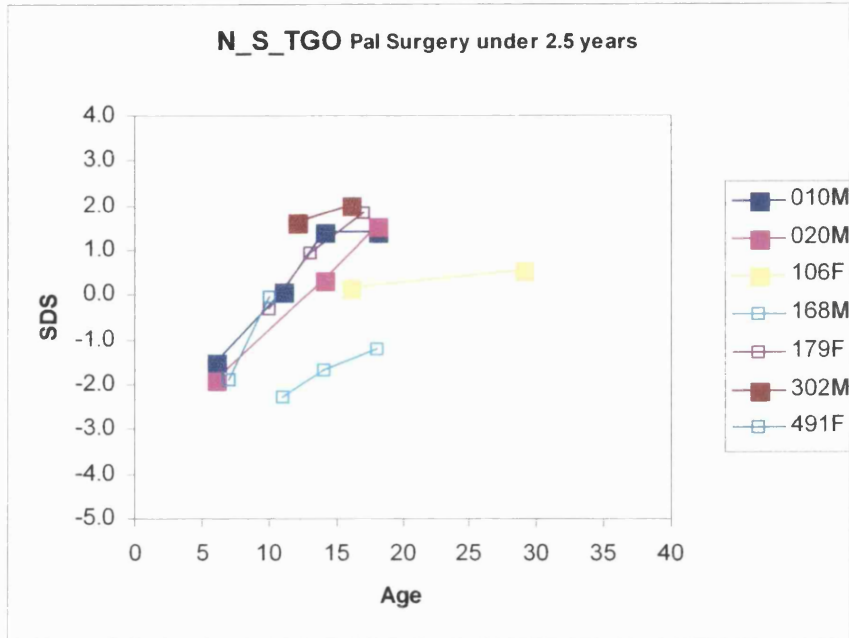
Fig. 5.3.72 PostPal N_S_TGO - Total Posterior Facial Height

N_S_TGO Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F

Fig. 5.3.73 PostPal N_S_TGO - Total Posterior Facial Height

N_S_TGO Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
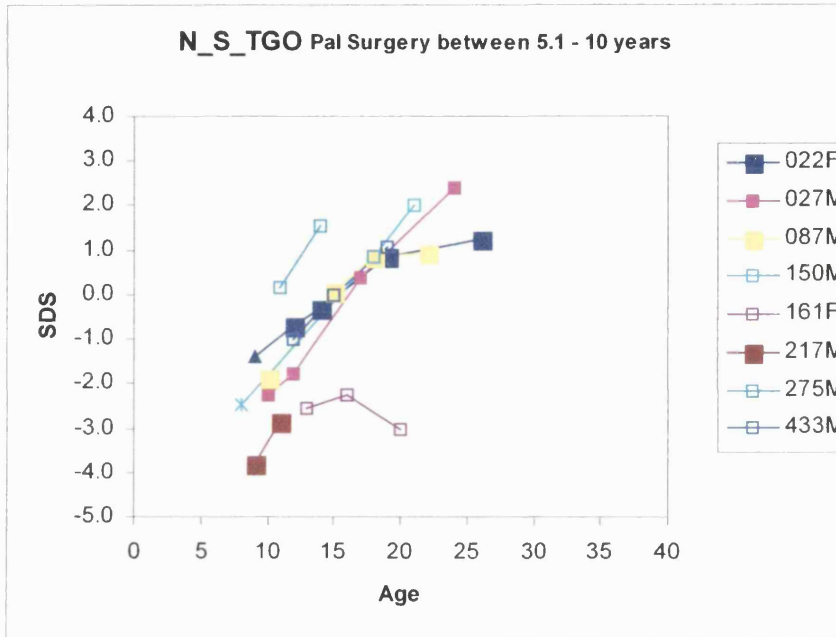
Fig. 5.3.74 PostPal N_S_TGO - Total Posterior Facial Height

N_S_TGO Pal Surgery between 10.1 - 18 years

Legend: 026F, 056F, 081M, 130M, 176M, 265M, 321F, 437M, 465M

Fig. 5.3.75 PostPal N_S_TGO - Total Posterior Facial Height

N_S_TGO Pal Surgery over 18.1 years

Legend: 042M, 076M, 132M, 178F, 371M

Axes: SDS (y-axis), Age (x-axis)

Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.18	1.21	0.23
2	0.27	19.19	**0.0001**
3	-0.01	-3.13	**0.002**

Fig. 5.3.76 PostPal S_N_Gn - Total Anterior Facial Height

S_N_Gn Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
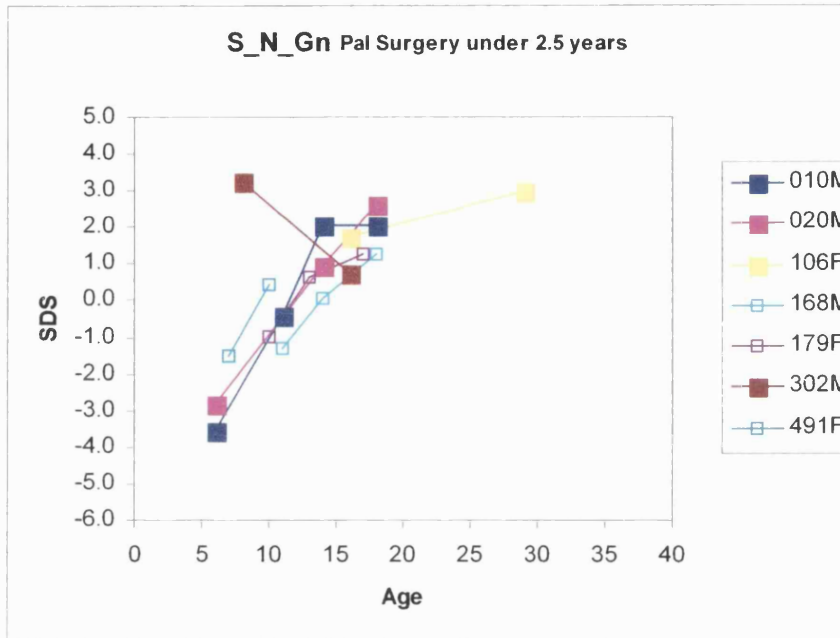
Fig. 5.3.77 PostPal S_N_Gn - Total Anterior Facial Height

S_N_Gn Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F

Fig. 5.3.78 PostPal S_N_Gn - Total Anterior Facial Height

S_N_Gn Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
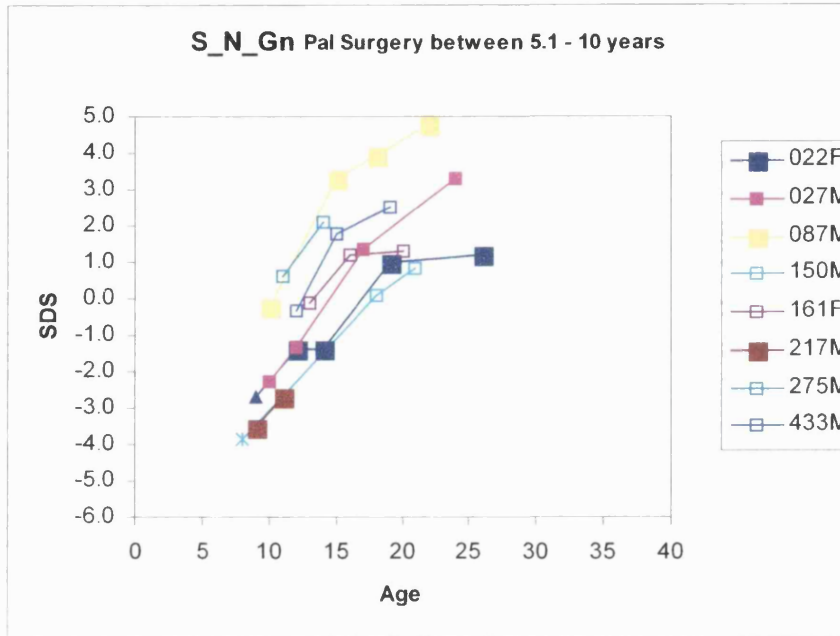
Fig. 5.3.79 PostPal S_N_Gn - Total Anterior Facial Height

S_N_Gn Pal Surgery between 10.1 - 18 years

Legend: 026F, 056F, 081M, 130M, 176M, 265M, 321F, 437M, 465M

Fig. 5.3.80 PostPal S_N_Gn - Total Anterior Facial Height

S_N_Gn Pal Surgery over 18.1 years

Legend: 042M, 076M, 132M, 178F, 371M

Y-axis: SDS
X-axis: Age

Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.88	4.55	**0.0001**
2	0.41	19.6	**0.0001**
3	-0.01	-2.56	**0.01**

7. Facial Heights

S_N_Ans   The anterior nasal spine showed a tendency to start with lower

than the Control mean at the beginning of data collection, although this was

not shown to be statistically significant. However, posterior placement of

ANS within the cranium is observed in both the Unop and PostLip cross-

sectional studies. Significant increases in growth acceleration are noted after

palate repair resulting in slightly higher SDS in comparison to the Control

population. A reduction in growth coefficient is seen when palatal surgery is

delayed. The eventual facial growth outcome after palate repair is an increase

in Upper Anterior facial height.

N_S_PTM & N_S_TGO   Statistical differences observed in both posterior

facial height variables were the accelerated growth coefficient over time and

in addition, the later the palate surgery is performed the less growth potential

is obtained. Upper Posterior facial heights grew to within normal limits when

compared with Controls, while Total Posterior facial heights resulted in an

overgrowth in length in comparison to the Control population.

S_N_Gn   Total anterior facial heights showed significantly low mean SDS.

Significant acceleration in growth coefficient over time resulted in an

overgrowth in facial height. This acceleration in growth diminished the later

the palatal surgery is performed.

In the Longitudinal study there were statistically different findings
between the PostPal groups and the Control population.

	Question	P Value	Description
S_N_ANS	2	***	Steep rise with age
	3	*	Fall with age at operation
TGO_Gn_ANS	1	***	Low mean SDS
	2	***	Steep rise with age
PTM_ANS_Gn	1	***	Very low mean SDS
	2	***	Steep rise with age
N_S_PTM	2	***	Steep rise with age
	3	*	Fall in rate of rise with age at operation
N_S_TGO	2	***	Very Steep rise with age
	3	**	Fall in rate of rise with age at operation
S_N_Gn	1	***	Low mean SDS
	2	***	Very Steep rise with age
	3	*	Fall in rate of rise with age at operation

8. Maxillary / Mandibular Plane and Mandibular Plane / Cranial Base Angles

Two variables were analysed:

Gn_MT1/ PTM_ANS   Gn_MT1/ N_S

One variable will be presented: Gn_MT1/ N_S

Fig. 5.3.81 PostPal Gn_MT1/N_S - Mandibular Plane Angle

Gn_MT1/N_S Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
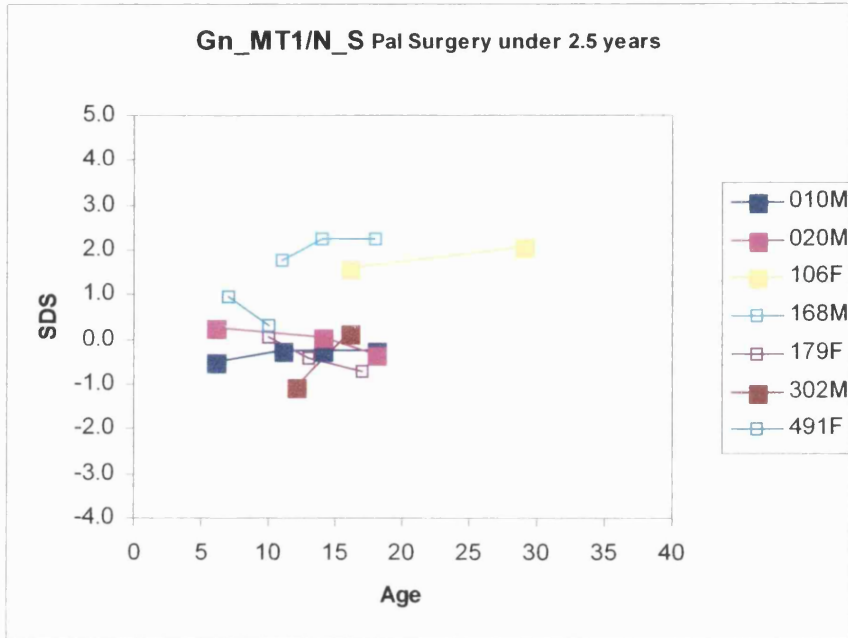
Fig. 5.3.82 PostPal Gn_MT1/N_S - Mandibular Plane Angle

Gn_MT1/N_S Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F
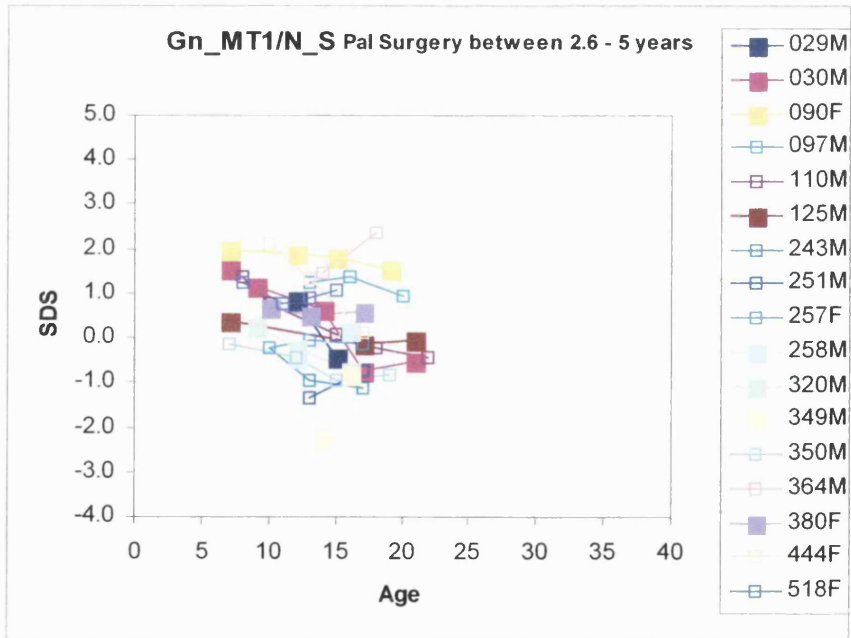
Fig. 5.3.83 PostPal Gn_MT1/N_S - Mandibular Plane Angle
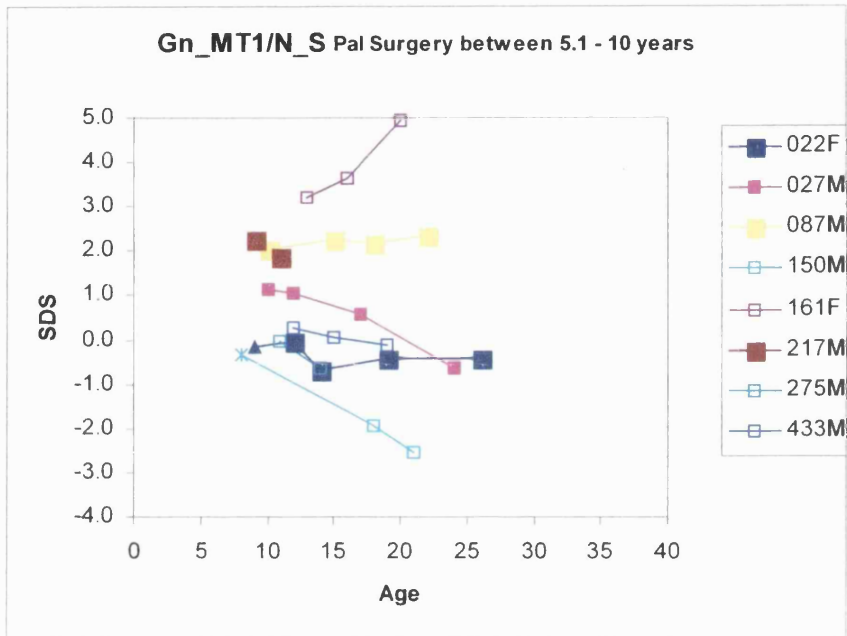
Fig. 5.3.84 PostPal Gn_MT1/N_S - Mandibular Plane Angle
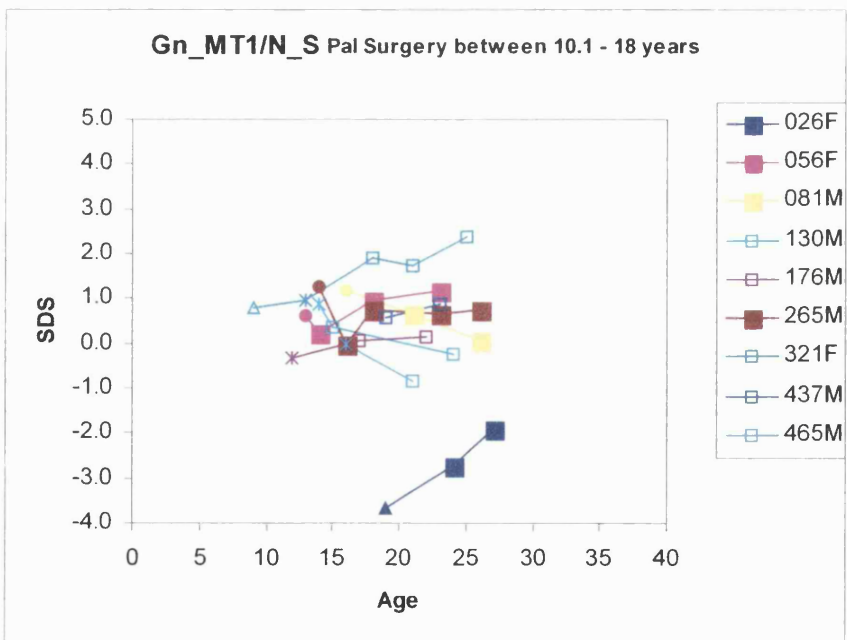
Fig. 5.3.85 PostPal Gn_MT1/N_S - Mandibular Plane Angle

Gn_MT1/N_S Pal Surgery over 18.1 years
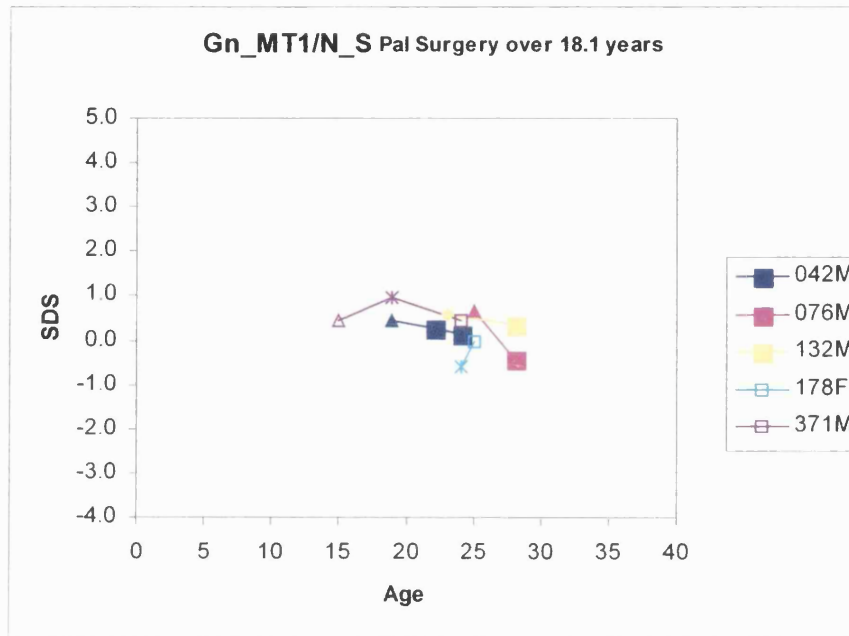
Statistical Analysis

Question	Coeff.	t ratio	P value
1	0.41	3.75	**0.0003**
2	-0.04	-3.01	**0.004**
3	0.006	1.85	0.07

8. Mandibular Plane/Cranial Base Angle

Gn_MT1/N_S   Statistically higher overall mean SDS than normal mandibular plane angles were observed. As the subject grows the growth coefficient reduces but remains within the Control population 95% confidence intervals.

In the Longitudinal study there were statistically different findings between the PostPal groups and the Control population.

	Question	P Value	Description
Gn_MT1/ PTM_ANS	1	***	High mean SDS
	2	**	Steep fall with age
Gn_MT1/ N_S	1	***	High mean SDS
	2	**	Steep fall with age

9. Incisor Relationships

Three variables were analysed

S_N/ AS_IS   II_AI/ Gn_MT1   AS_IS/ II_AI

All three variables are presented.

Fig. 5.3.86 PostPal S_N/AS_IS - Upper Incisal Angle
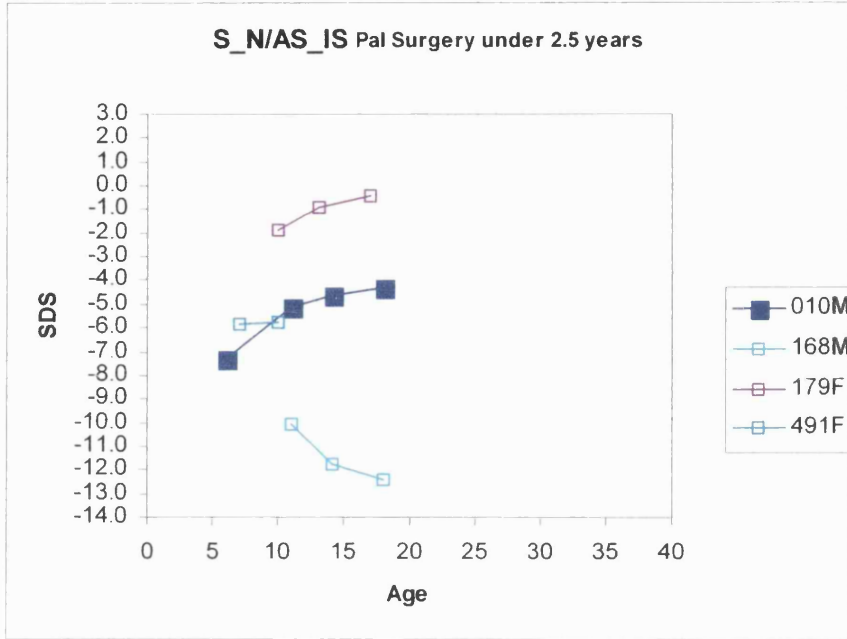
Fig. 5.3.87 PostPal S_N/AS_IS - Upper Incisal Angle
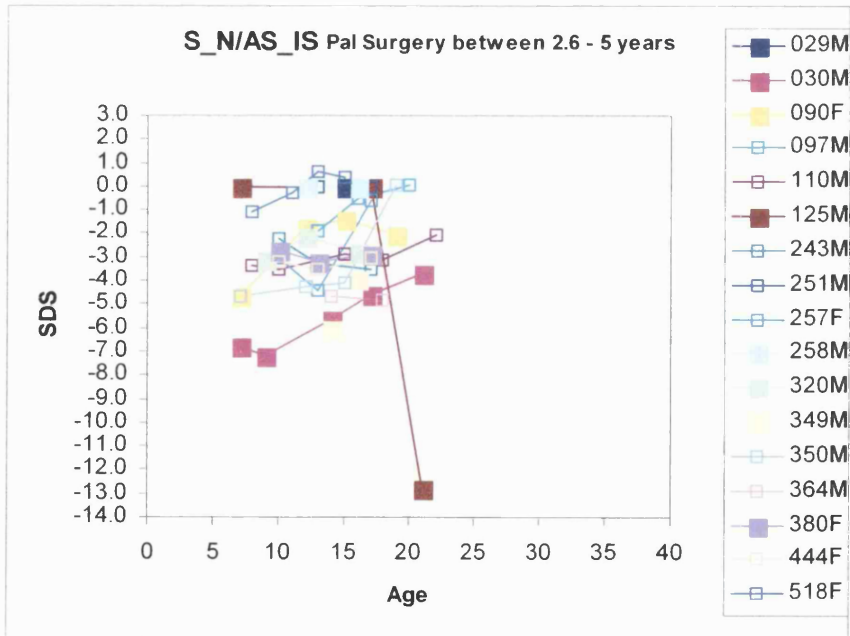
Fig. 5.3.88 PostPal S_N/AS_IS - Upper Incisal Angle

S_N/AS_IS Pal Surgery between 5.1 - 10 years

Legend: 022F, 027M, 087M, 150M, 161F, 217M, 275M, 433M
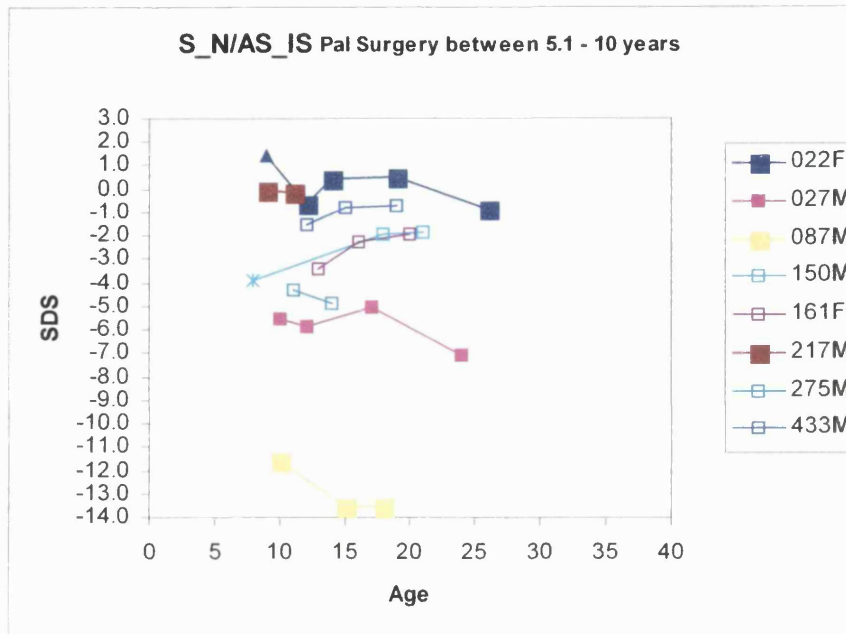
Fig. 5.3.89 PostPal S_N/AS_IS - Upper Incisal Angle

S_N/AS_IS Pal Surgery between 10.1 - 18 years

Legend: 056F, 081M, 176M, 265M, 321F, 437M, 465M
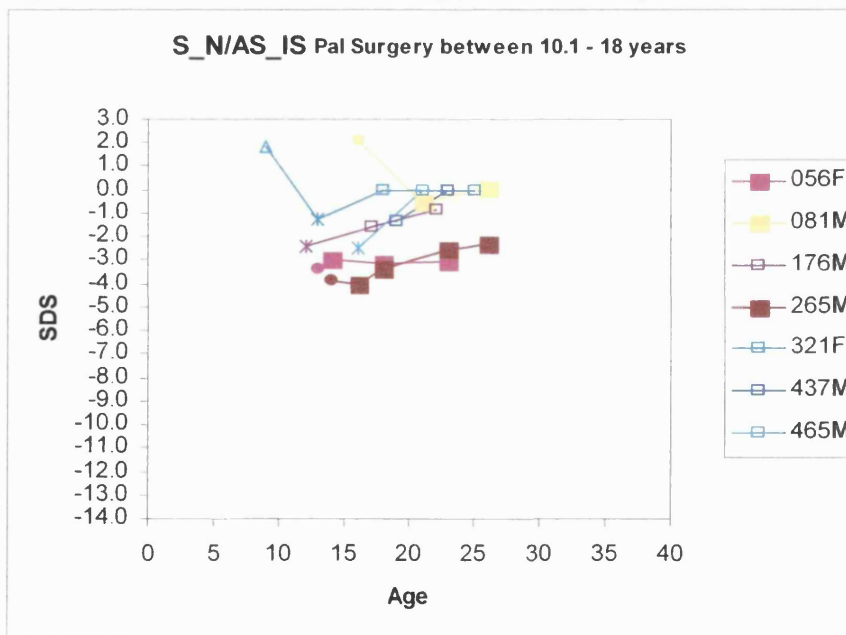
Fig. 5.3.90 PostPal S_N/AS_IS - Upper Incisal Angle

S_N/AS_IS Pal Surgery over 18.1 years

Legend:
- 042M
- 076M
- 132M
- 178F
- 371M

Y-axis: SDS
X-axis: Age
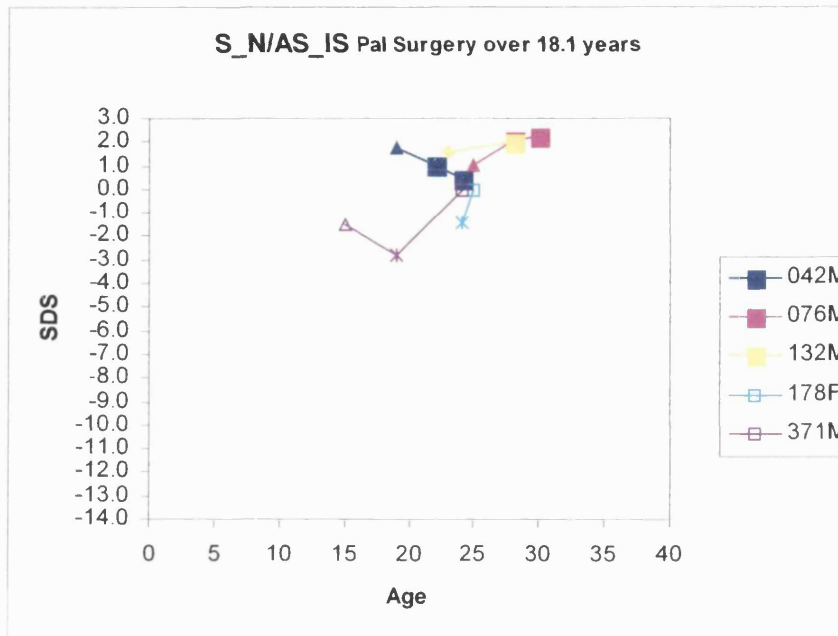
Statistical Analysis

Question	Coeff.	t ratio	P value
1	-3.17	-9.98	**0.0001**
2	0.19	3.33	**0.001**
3	-0.02	-0.98	0.33

Fig. 5.3.91 PostPal II_AI/Gn_MT1 - Lower Incisal Angle

II_AI/Gn_MT1 Pal Surgery under 2.5 years

Legend: 010M, 020M, 106F, 168M, 179F, 302M, 491F
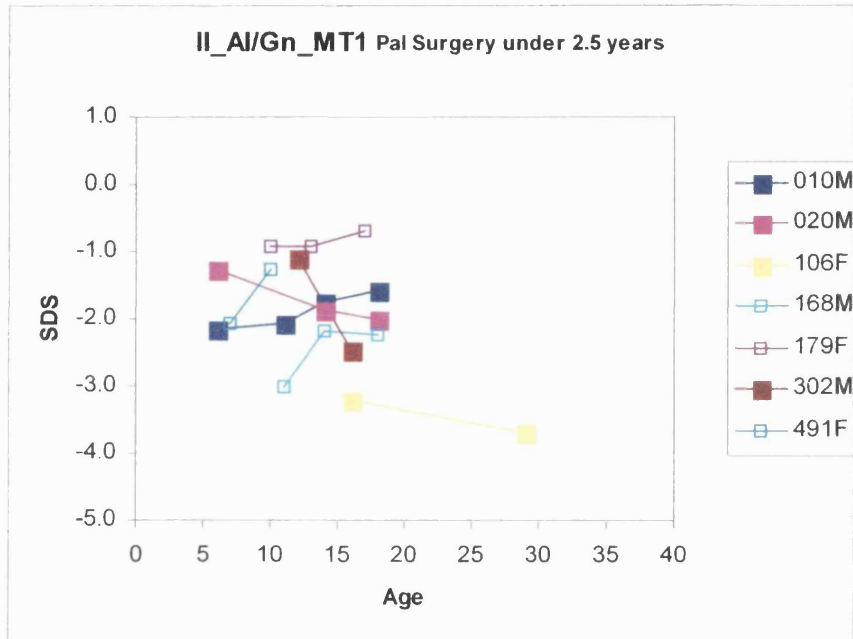
Fig. 5.3.92 PostLip II_AI/Gn_MT1 - Lower Incisal Angle

II_AI/Gn_MT1 Pal Surgery between 2.6 - 5 years

Legend: 029M, 030M, 090F, 097M, 110M, 125M, 243M, 251M, 257F, 258M, 320M, 349M, 350M, 364M, 380F, 444F, 518F
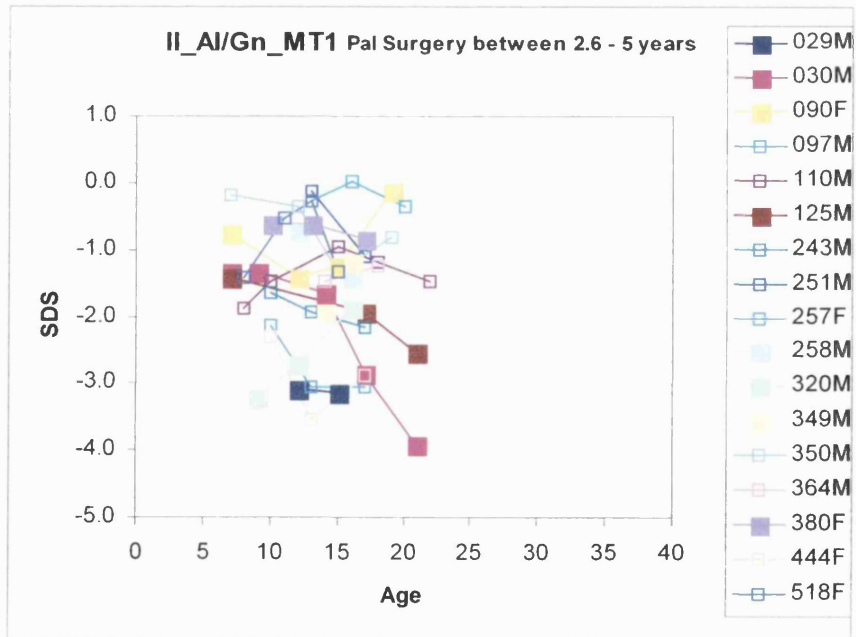
Fig. 5.3.93 PostLip II_AI/Gn_MT1 - Lower Incisal Angle

II_AI/Gn_MT1 Pal Surgery between 5.1 - 10 years
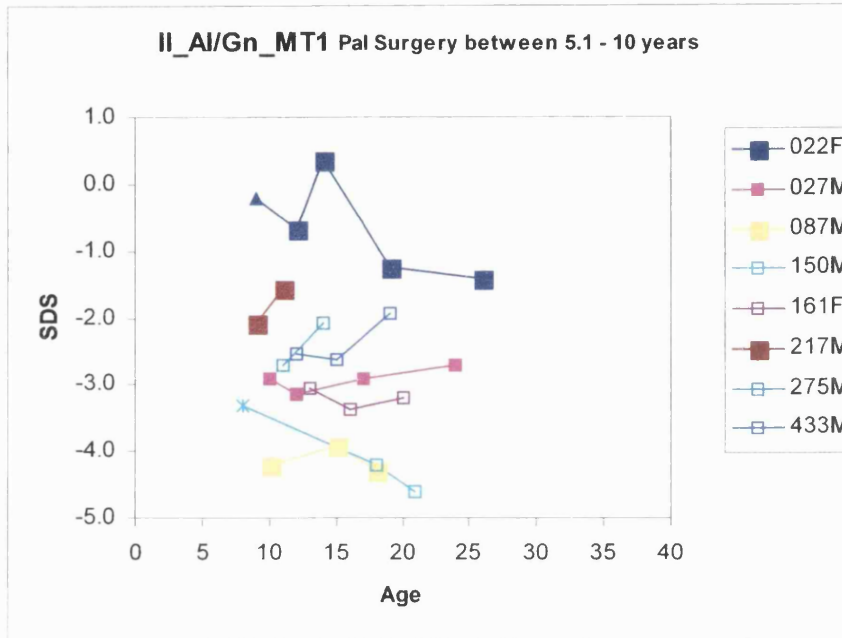
Fig. 5.3.94 PostLip II_AI/Gn_MT1 - Lower Incisal Angle

II_AI/Gn_MT1 Pal Surgery between 10.1 - 18 years

Fig. 5.3.95 PostLip II_AI/Gn_MT1 - Lower Incisal Angle

II_AI/Gn_MT1 Pal Surgery over 18.1 years
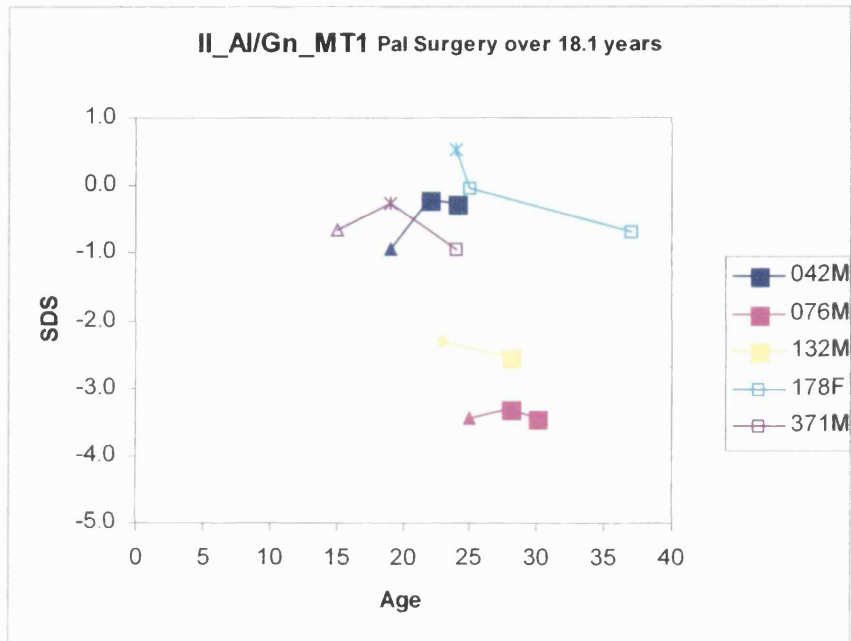
Statistical Analysis

Question	Coeff.	t ratio	P value
1	-1.72	-16.92	**0.0001**
2	-0.04	-2.91	**0.005**
3	-0.001	-0.34	0.74

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Fig. 5.3.96 PostPal AS_IS/II_AI - Inter-incisal Angle

AS_IS/II_AI Pal Surgery under 2.5 years
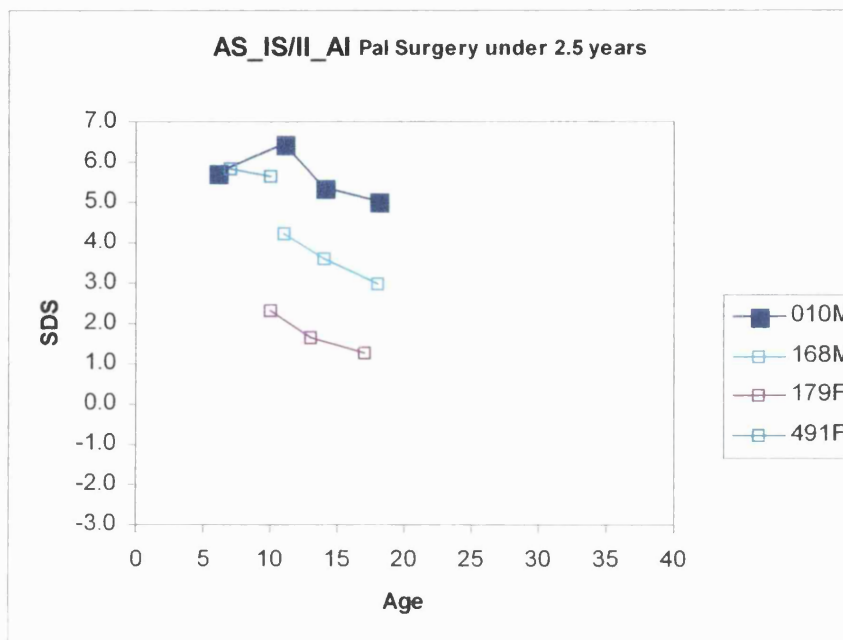
Fig. 5.3.97 PostPal AS_IS/II_AI - Inter-incisal Angle

AS_IS/II_AI Pal Surgery between 2.6 - 5 years

Fig. 5.3.98 PostPal AS_IS/II_AI - Inter-incisal Angle

AS_IS/II_AI Pal Surgery between 5.1 - 10 years
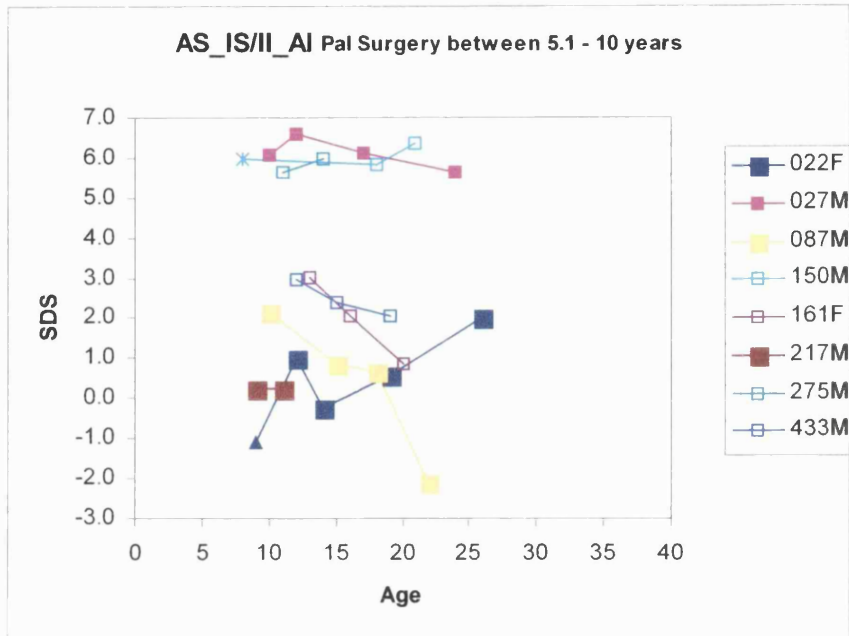
Fig. 5.3.99 PostPal AS_IS/II_AI - Inter-incisal Angle

AS_IS/II_AI Pal Surgery between 10.1 - 18 years
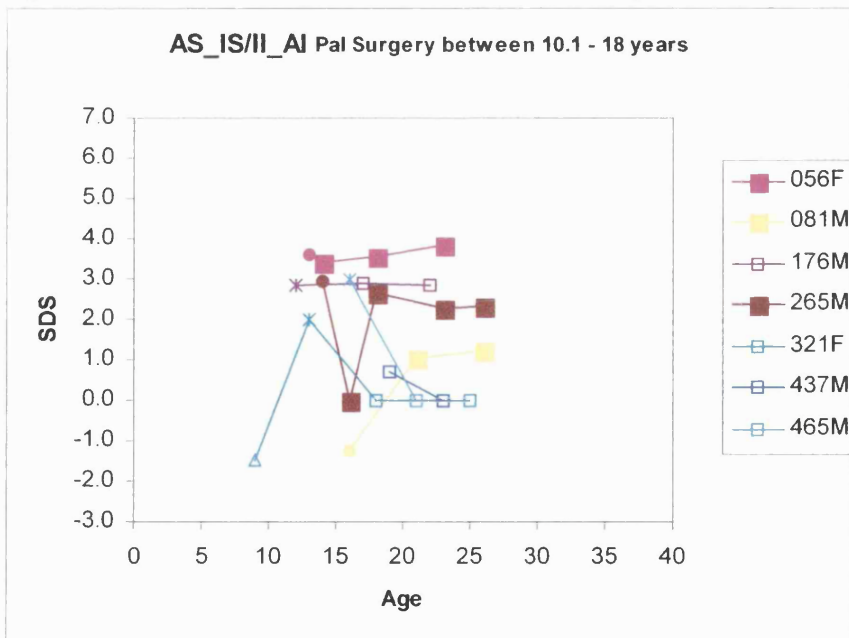
Fig. 5.3.100 PostPal AS_IS/II_AI - Inter-incisal Angle
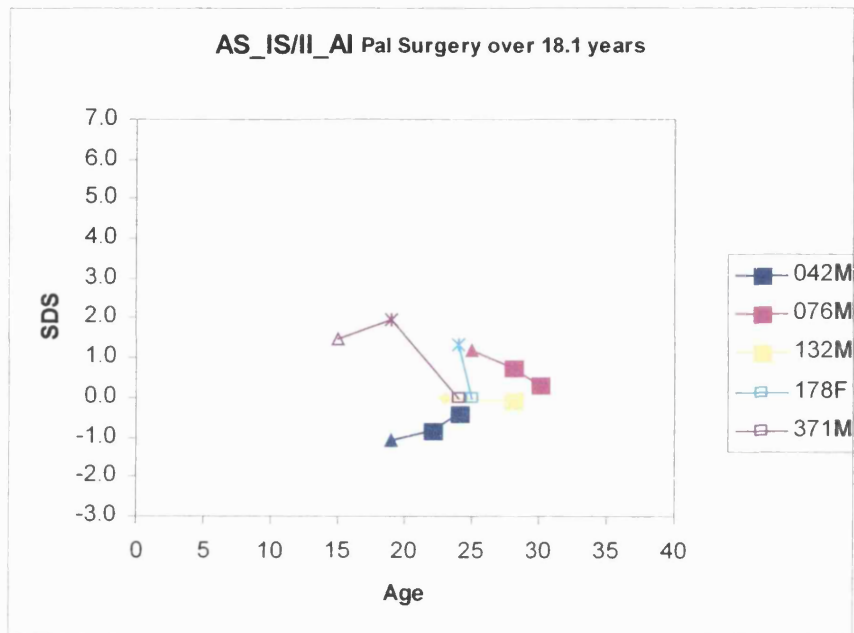
Statistical Analysis

Question	Coeff.	t ratio	P value
1	3.02	13.94	**0.0001**
2	-0.08	-3.16	**0.002**
3	0.02	1.93	0.06

9. Incisor Relationships

S_N/AS_IS   The Upper incisal angle presents with significantly low mean SDS in comparison to the Control population. The Upper incisal angle in the PostPal groups has shown lower than average incisal angles. Mixed growth effects are observed over time, which also differ from the rate of growth in the Controls.

II_AI/Gn_MT1   The Lower incisal angle also presents with significantly low mean SDS in comparison to the Control population. Further reduction in lower incisal angle is observed over time. The continued retroclination of the Lower incisors was found to be statistically significant in the PostPal BCLP sample.

AS_IS/II_AI   The inter-incisal angle was shown to be a much greater angle in the PostPal groups than in the Control population. Although some reduction in angulation occurred over time, the resultant inter-incisal angle remained larger than the Controls. However, the later the palatal surgery is performed the less of a growth effect is observed. A higher inter-incisal angle is seen the earlier the palate is repaired.

In the Longitudinal study there were statistically different findings between the PostPal groups and the Control population.

	Question	P Value	Description
S_N/ AS_IS	1	***	Very low mean SDS
	2	**	Mixed growth coefficients with age
II_AI/ Gn_MT1	1	***	Low mean SDS
	2	**	Fall with age
AS_IS/ II_AI	1	***	Very high mean SDS
	2	**	Fall with age
	3	*	Fall with age at operation

F) Facial growth outcomes beyond 18 years of age

This last section of the results chapter presents an overall view of all subject groupings beyond 18 years of age. In this section only, are the males and the females pooled for analysis. Few subjects in the early palatal repair groups were over the age of 18 at the last data collection, for this reason the males and females were pooled. Cross-sectional analysis presents the actual variable measurements and not the SDS in this final facial growth results section. Regression was used to test for any statistically significant differences between the Controls and the BCLP subject groups. A representative group of 9 key variables showing statistically significant outcome measures are presented.

The age of 18 reflects the late pubertal growth results, only some of the subjects are considered to be post pubertal.

Fig. 5.4.1 Maxillary Protrusion

SNA Measured over 18 years
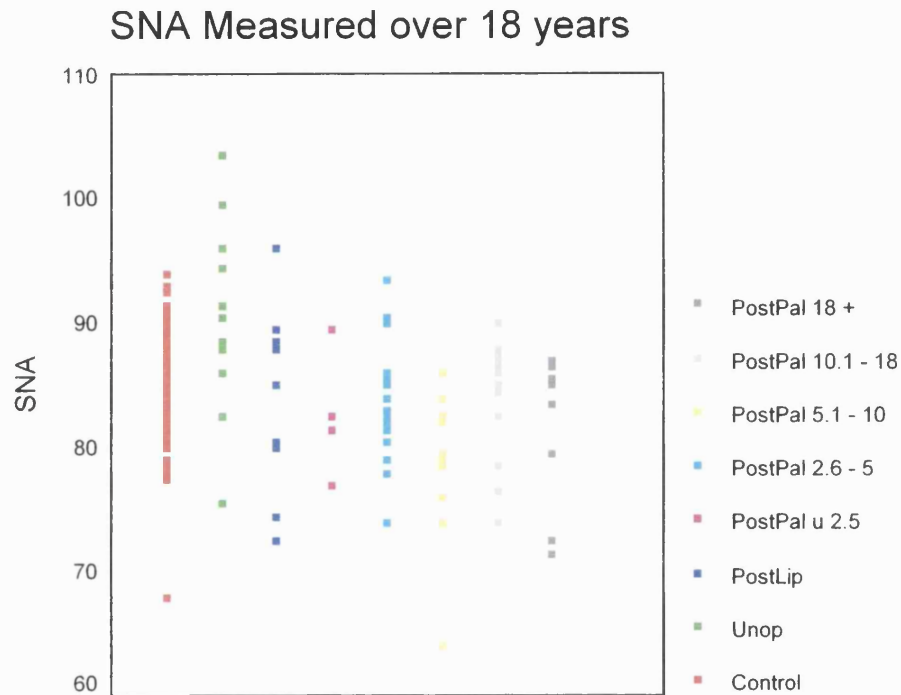
	Unop	PostLip	U 2.5	2.6 -5	5.1 -10	10.1 -18	18+
Sig.	**0.000**	0.18	0.11	0.23	**0.000**	0.6	0.06

The protrusion of the premaxilla can clearly be seen in the Unop subject. This protrusion is reduced after lip repair and further reduction after palatal repair. Statistical differences were noted, excessive protrusion in the Unoperated group and more retroclination in the 5.1 - 10 PostPal repair group.

Fig.5.4.2 Maxillary Protrusion

SNAns Measured over 18 years
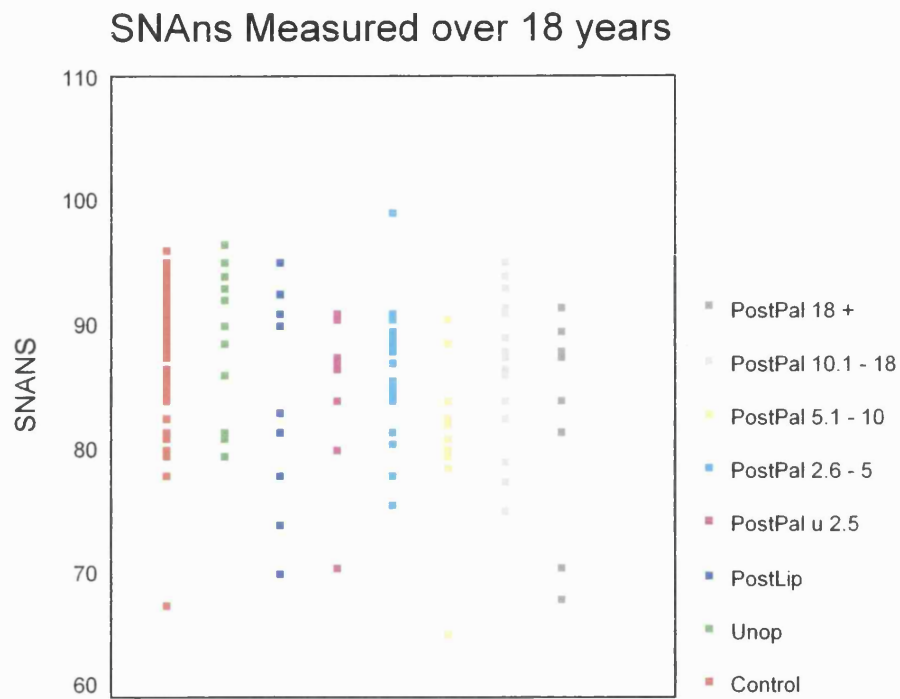
	Unop	PostLip	U 2.5	2.6 -5	5.1 -10	10.1 -18	18+
Sig	0.83	0.08	0.08	0.09	**0.002**	0.08	**0.01**

Statistically significant differences were observed between subject groups who had palate surgery between 5.1-10 years and over the age of 18 years in this variable.

Fig.5.4.3 Maxillary Length

Ans_Ptm Measured over 18 years
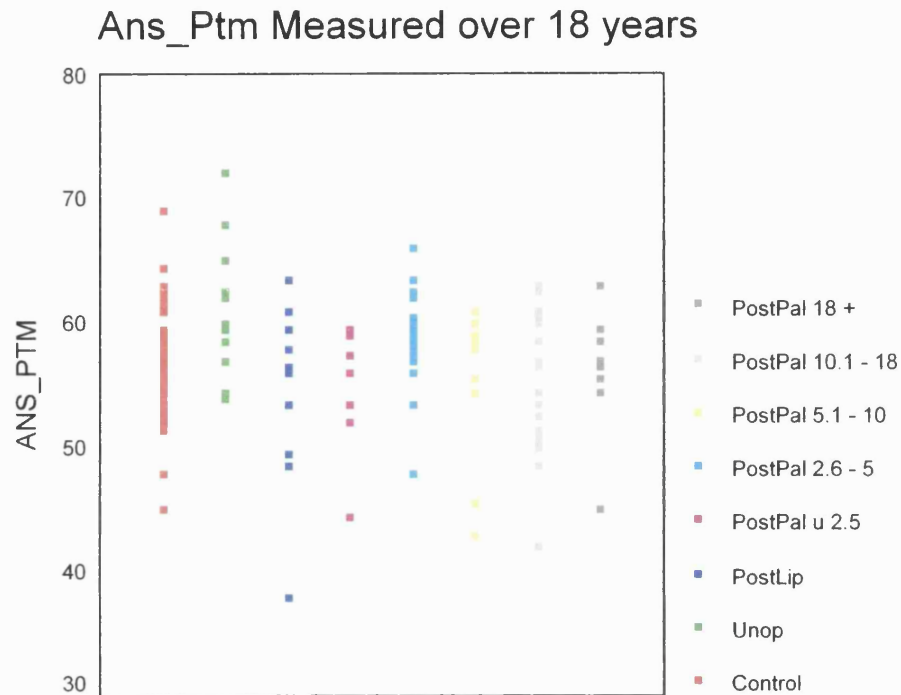
	Unop	PostLip	U 2.5	2.6 -5	5.1 -10	10.1 -18	18+
Sig	**0.001**	0.12	0.32	0.15	0.10	0.17	0.63

The overgrowth of the maxilla can clearly be seen in the Unoperated subjects. Lip repair reduces the palatal length. No significant differences to palatal length were attributed to the age at which palatal surgery was performed.

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Fig.5.4.4 Facial Convexity Angle

NAPg Measured over 18 years
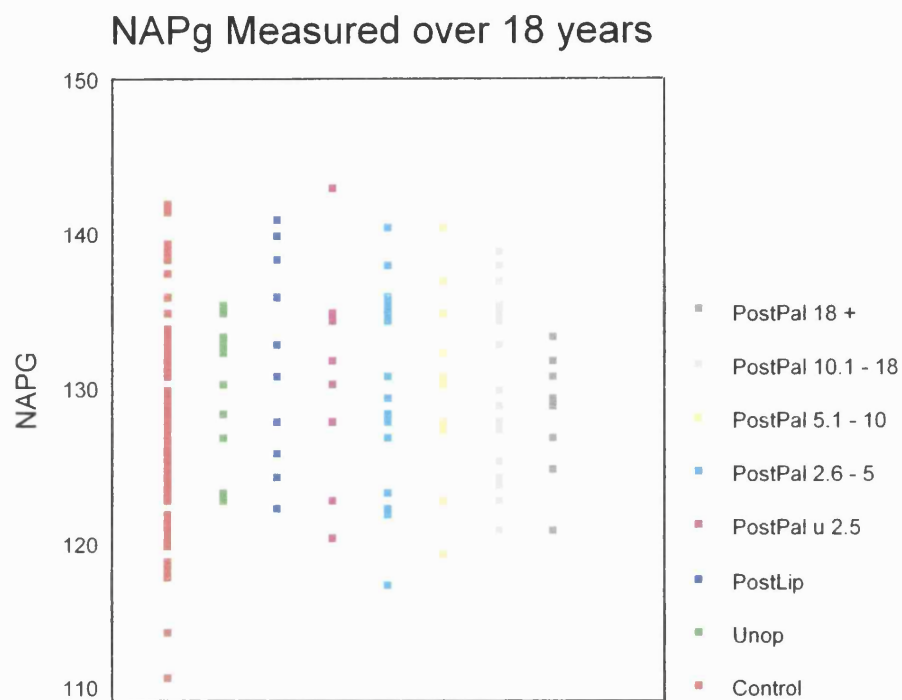
	Unop	PostLip	U 2.5	2.6 -5	5.1 -10	10.1 -18	18+
Sig	0.26	0.03	0.2	0.2	0.08	0.04	0.46

No Statistical differences were noted in this variable.

Fig.5.4.5 Mandibular Protrusion

SNB Measured over 18 years
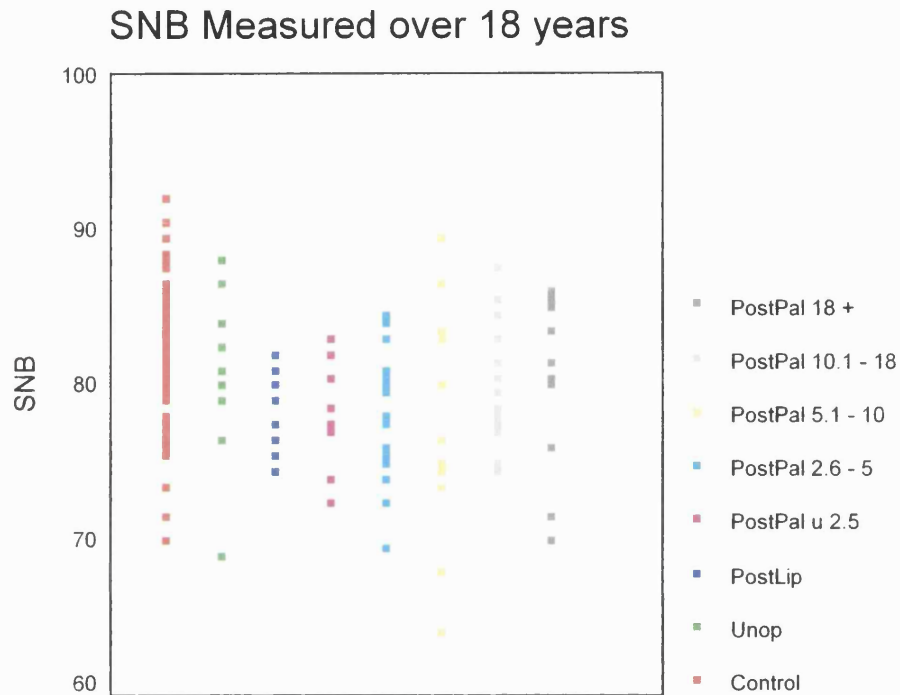
	Unop	PostLip	U 2.5	2.6 -5	5.1 -10	10.1 -18	18+
Sig	0.32	0.07	**0.009**	**0.002**	**0.001**	0.03	0.11

A reduction in mandibular protrusion was observed in the PostLip group but was not found to be statistically significant. The significant differences were observed in the early palatal surgery group under 2.5 years and in the delayed hard palate surgery groups 2.6 – 5 and 5.1 – 10 years.

Fig.5.4.6 Ramus Length

Ar_TGO Measured over 18 years
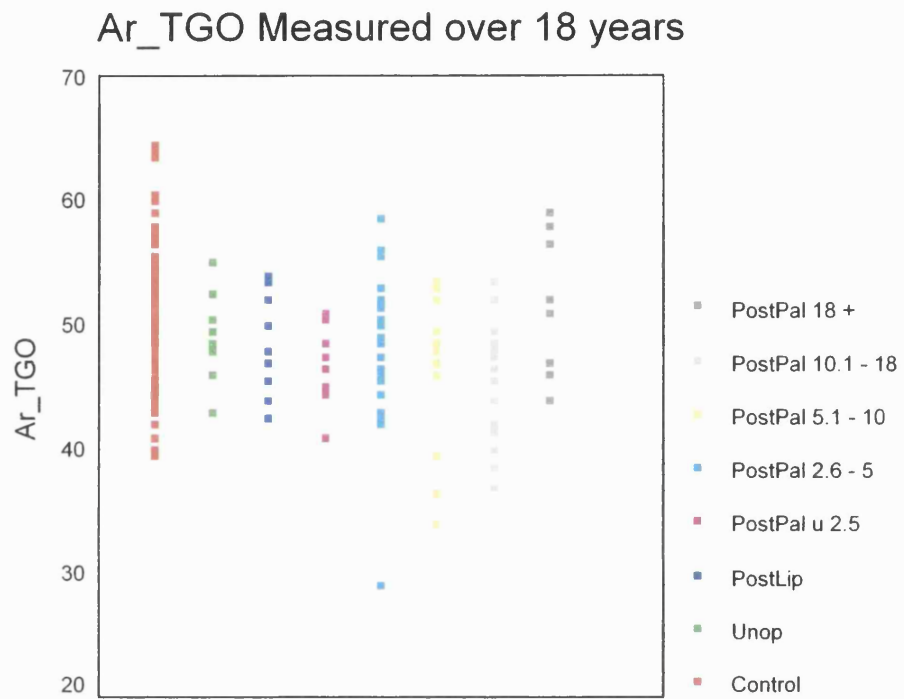
	Unop	PostLip	U 2.5	2.6 -5	5.1 -10	10.1 -18	18+
Sig	0.31	0.16	0.17	0.05	0.03	**0.001**	0.88

Statistical differences were observed in Ramus length in subjects who had palate surgery between 10.1 - 18 years.

Fig.5.4.7 Mandibular Length

TGO_Gn Measured over 18 years
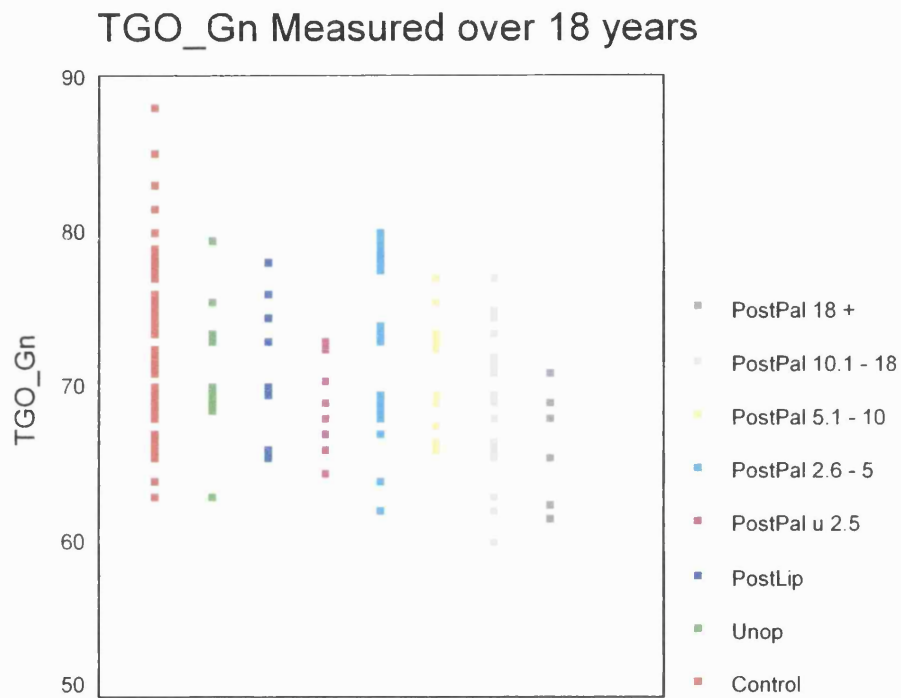
	Unop	PostLip	U 2.5	2.6 -5	5.1 -10	10.1 -18	18+
Sig	0.25	0.39	**0.005**	0.69	0.12	**0.002**	**0.000**

Statistically shorter mandibular lengths were observed in subjects who had palatal surgery under 2.5 years old, 10.1 – 18 year group and the post pubertal group.

Fig.5.4.8 Upper Anterior Facial Height (Perpendicular Distance)

S_N_Ans Measured over 18 years

Legend:
- PostPal 18 +
- PostPal 10.1 - 18
- PostPal 5.1 - 10
- PostPal 2.6 - 5
- PostPal u 2.5
- PostLip
- Unop
- Control
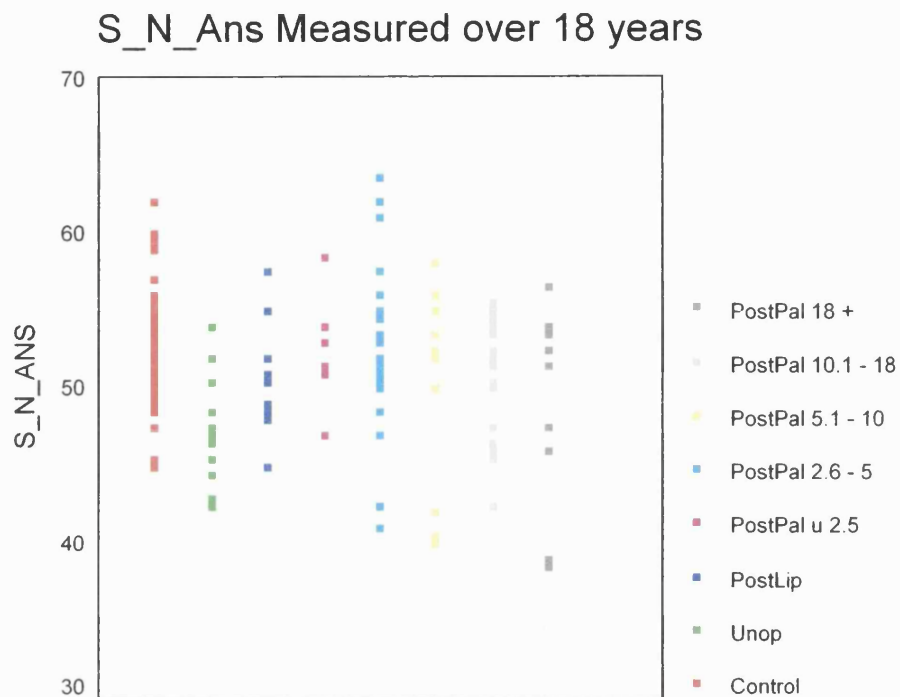
	Unop	PostLip	U 2.5	2.6 -5	5.1 -10	10.1 -18	18+
Sig	**0.000**	0.21	0.92	0.49	0.17	0.12	0.02

Statistically shorter upper anterior facial heights are observed in the Unoperated group.

Fig.5.4.9 Total Anterior Facial Height (Perpendicular Distance)

S_N_Gn Measured over 18 years
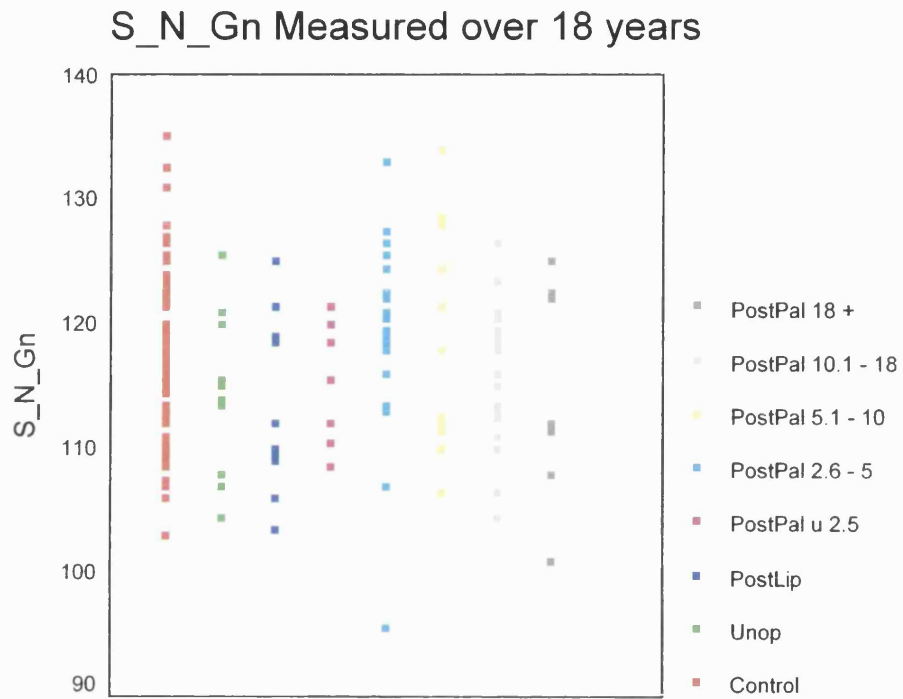
	Unop	PostLip	U 2.5	2.6 -5	5.1 -10	10.1 -18	18+
Sig	0.23	0.25	0.45	0.07	0.83	0.02	0.65

No statistical differences were observed for this variable.

Chapter 6

DISCUSSION OF RESULTS AND CONCLUSIONS IN RELATION TO
THE HYPOTHESES TESTED

This study was aimed at investigating the unoperated subject, the effects of lip

surgery, the timing of palatal surgery and the variation in outcome, with different

ages at palatal surgery, on facial growth in BCLP Sri Lankan subjects. A

retrospective mixed cross-sectional and longitudinal cephalometric study was

undertaken. All results, discussion of those results and conclusions refer to

subjects from Sri Lanka.

The initial premise for this facial growth and morphology study was based upon 4

hypotheses. This chapter will address both the discussion of the results and the

conclusions in relation to these hypotheses.

The results of this study are complicated. Some of the hypotheses are upheld;

other hypotheses are partially fulfilled or not upheld. The complexity of the

results presented in this study is a reflection of the underlying heterogeneity of

facial growth and morphology, variation in both the method and timing of

surgery and the combined effects of iatrogenic and intrinsic effects on growth

outcome among Sri Lankan BCLP subjects.

The complexity of this study and subsequent results are confounded by multiple

factors: heterogeneity of the material studied; nature and timing of surgery,

intrinsic versus iatrogenic deformity, effects of malnutrition and the psychological implications on the somatic and facial growth in the congenitally disfigured subject.

Heterogeneity of the material studied

Results of the Repeatability Study

The results of the repeatability study show a highly consistent repeated cephalometric digitization method. The error of 0.63° for angular measures and 0.51mm for linear measures falls well within published accepted norms for a cephalometric study, (Battagel, 1993).

Assignment to groups by age

The longitudinal study included all subjects with a minimum of 2 or a maximum of 6 lateral skull radiographs to be able to plot each individual's growth coefficient over time. The BCLP subjects were divided into subgroups based on the age at which palatal surgery occurred. The five groups were divided into age ranges that might be considered to nearly represent current practices around the world, with an additional post pubertal group for comparison. The division into five groups by age at which palatal surgery took place, is as far as I'm aware, the first attempt to analyse this type of data in a longitudinal fashion. Although longitudinal data has previously been published the data has been analysed in a cross-sectional manner.

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Justification of Sample size

Whilst there are 81 patients in this study who could all have been considered to be in one group it was felt that such an approach would limit the analysis that attempts to examine the age at which surgery is undertaken. However, separate analysis of the whole sample into the Unoperated, PostLip and PostPal groups together with further separation by age at palatoplasty has resulted in reduced sample sizes. The ratios of males to females in this study were 3:1. In the literature the response to small sample sizes has been to pool the sexes and analyse the males and females together. Pooling males and females within the same study group disguises the subtle growth differences exhibited by each sex. In general females reach their maximum growth potential earlier than males, whilst males realize an even higher growth potential but later. This is interesting because in the cleft population the female subjects would attain their maximum growth and plateau with males continuing to grow beyond this level and not plateau until 2 - 3 years later. Pooling of the sexes masks the differences between them. This phenomenon is illustrated in Fig.6.1, the facial growth results of the UCLP & BCLP subjects treated by the Oslo team, (Semb, 1991). In her paper Semb analyses the facial growth results using a total cleft group mean, which pools males and females in one group. From the graph the sexual differences between males and females can clearly be seen, (Semb and Shaw, 1990; Semb and Shaw, 1998). Semb further complicates analysis by examining the compared means of her cleft population thus hiding important statistical information about

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the spread of the data or the sample's standard deviation at a given age between subjects. In addition fewer females than males skew the mean value when compared as one pooled value. The mean value approximates to the male value, obscuring the female differences. This can be seen quite clearly in Fig 6.1 between the ages of 11 – 13 years for the UCLP and between 13 – 15 years in the BCLP.
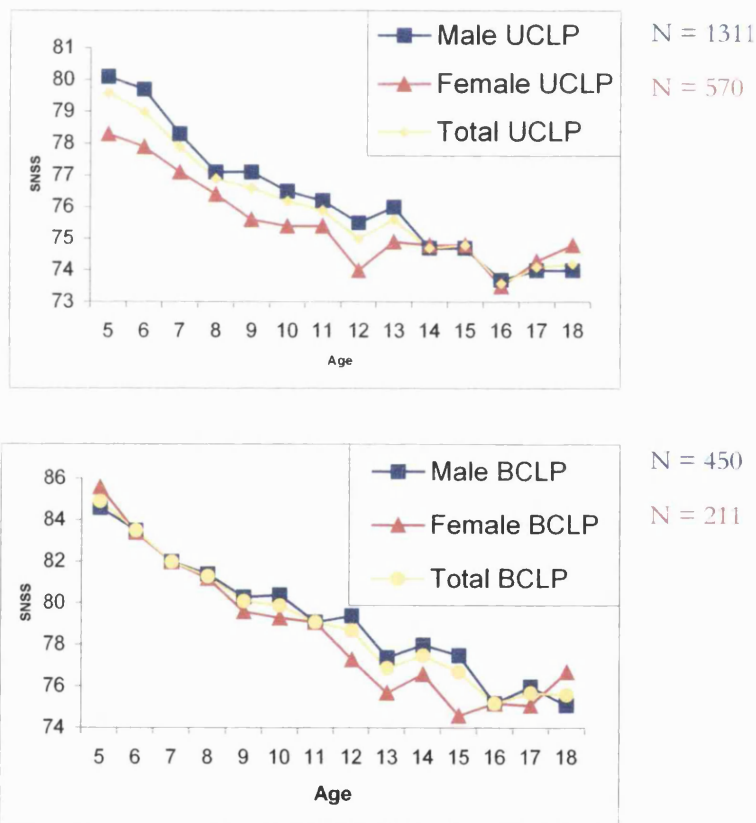
Fig. 6.1 Maxillary Protrusion, SNSS, in subjects treated by the Oslo team.

(N = *no. of recordings*)

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In summary females reach their poorest results at 12 years in the UCLP sample and between 13 - 15 years in the BCLP sample, whereas males do not reach theirs until 16 - 18 years. Therefore pooling at a chronological age distorts and disguises the real biological differences between the sexes.

All the facial growth variables in this study were converted into Standard Deviation Scores, SDS, which were used to enable direct comparison with an age, sex matched control subject's facial growth centile. This practice obviates the need for pooling the sexes. The SDS rates each individual cleft subject against a control population mean, eliminating the possible erroneous interpretation of results caused by pooling the sexes which could nullify clinically significant growth changes with age.

Limitations of the Study Design
Inherent difficulties exist in both cross-sectional and longitudinal studies, (Farkas, 1996). The advantages of a cross-sectional study are a minimum number of investigators, enabling large data collection in a relative short time period. This provides a cost effective study to collect a representative population sample, and a precise ethnic and socio-economic study mix can be recruited. The main disadvantage of a cross-sectional study is their limited value as a growth study. Longitudinally designed studies enable information to be collected on the growth pattern, changes in growth and the acceleration of growth to be examined. However due to the longevity of a longitudinal study there is an increase in study

cost, more investigators are needed and the sample size inevitably decreases over the study period due to illness, death, migration or withdrawal from the study. In addition the collection of growth data over an 18-year period or longer in each age group predetermines that any statistical analysis of the material or publication to be 20-years after the study conception. Longitudinal studies are time and cost dependent. The cost for the team, logistics of the data collection and analysis increase over the study period, requiring large investment financially and in human resources. For these reasons this study's design was a retrospective mixed cross-sectional and longitudinal study. The period of data collection for this study was from 1984 - 2002.

Nature and Timing of Surgery

Craniofacial growth and development is dependent on the rate, timing, direction and magnitude of cellular division and tissue differentiation, (Enlow and Hans, 1996). Growth is not 'programmed' within the bone itself or its enclosing membranes. The 'blueprint' for the design, construction and growth of the bone lies within the interrelationship of the bone and its surrounding structures. The muscles, tongue, lips, cheeks, mucosa, nerves, blood vessels, airway, pharynx, and cranium provide information signals that pace the tissues producing a bone's development. Growth is a composite change of all these components. An infant's palate is not the same palate in the adult simply grown larger. The palate in later childhood is not the same infant tissue with more added and does not occupy the

same actual position. The newborn infant is characterized with a broad cranium and a vertically short face. The nasal and oral regions are still diminutive and the mandibular ramus vertically short because it is linked in development to the later-maturing nasal and dental regions. During later childhood and into adolescence vertical nasal enlargement keeps pace with the growing body and the dental/oral development into adulthood. Increasing vertical ramus length lowers the mandible and the downward forward translocation of the Maxilla changes the skeletal profile from the wide face of the newborn infant to the long face pattern of the adult. Many factors influence the growing palate, developmental rotations, and displacements in conjunction with growth at sutures and multiple remodeling movements that relocate it to progressively new positions. This remodeling adjusts the size, shape, alignment and position continually throughout the growth period. Example of these changes can be seen in Fig. 6.2 & 6.3. Bone remodeling occurs when bone is simultaneously being resorbed and deposited. Displacement is a similar growth concept to the osteoclastic and osteoblastic activity in orthodontic tooth movement.
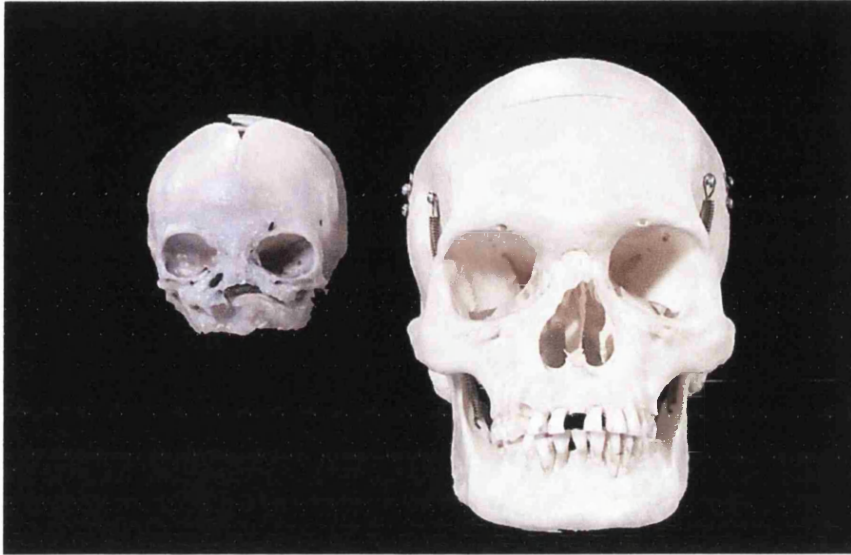
Fig 6.2 Skull morphology of the newborn Unoperated UCLP and an Adult Skull.
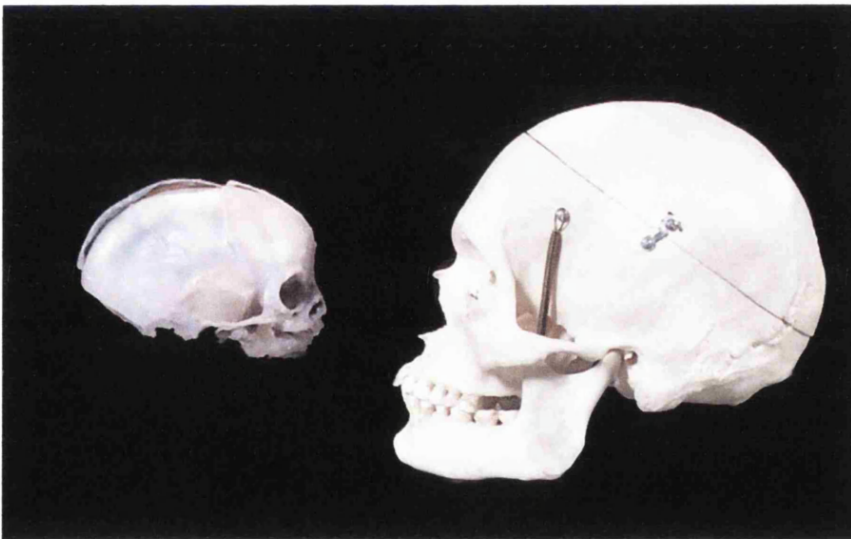
Fig 6.3 Skull morphology of the newborn Unoperated UCLP and an Adult Skull.

The newborn unoperated UCLP subject was photographed to illustrate the significant differences in ratios of the cranium to the facial skeleton in the newborn and the mature adult.

The original purpose of cephalometrics was as a clinical tool to study malocclusion and underlying skeletal disproportions in the growth patterns of the craniofacial complex. Cephalometric analysis evaluates dentofacial form and skeletal relationships. However, the interrelationship of the bone and the impact of the surrounding muscular, tissue and structural development must not be disregarded.

Prior to examining the nature and timing of any surgery to the underlying skeletal growth, the natural development of the unoperated subject should be assessed. The unoperated subject provides information on the baseline intrinsic cleft growth pattern with no surgical intervention.

Hypothesis 1

The unoperated subject has the ability to achieve normal growth or an overgrowth of the maxilla.

This hypothesis is upheld. In the unoperated bilateral cleft lip and palate subject the protrusive premaxilla is unrestrained and protrusion of the premaxillary segment remains throughout the facial growth period. The unoperated subject has the ability to achieve normal growth or an overgrowth of the maxilla. The initial characteristics of the unoperated subject at birth persist throughout the facial growth period.

In the unoperated subjects an overgrowth of the premaxilla and the maxilla is evident, resulting in a positive Class I or Class II incisor relationship. The initial characteristics of the newborn BCLP subject persist during growth see Figs. 6.4 & 6.5. The prominent premaxilla, wide alar bases, often laterally deviated premaxillary segment, short columella, rudimentary prolabium with no muscle attachment can be seen. The newborn baby and 49-year-old man present with the same morphology, substantiating the reports that the initial cleft characteristics persist throughout facial growth, (Semb, 1991; Filho et al., 1998). The unoperated subject demonstrates the underlying growth potential in every newborn BCLP subject. This baseline for the natural development of the BCLP subject with no surgical intervention enables direct comparison with the operated subjects. The resulting post surgical facial growth characteristics may enable demarcation between iatrogenic or intrinsic cleft features. This study and previous studies on UCLP subjects clearly demonstrate that unoperated subjects with BCLP or UCLP have the overall potential to grow nearly normally, though with localized areas of distortion.

Thus, for the first time this study has demonstrated that the unoperated subject presented with an *intrinsically* different skeletal pattern to the healthy non-cleft Sri Lankan. On examination the anterior nasal spine and the pterygo-maxillary fissure are superiorly and posteriorly placed whilst Basion is superiorly and anteriorly placed. The initial appearance of an overgrowth of the maxilla in the unoperated

subject is misleading; the maxillary protrusion is merely reflecting the underlying protrusion of the premaxillary segment. Further explanations of these findings are discussed throughout this chapter.

Fig. 6.4 A new born unoperated BCLP subject

Fig. 6.5 Sam, a 49-year unoperated BCLP subject

Note the lateral segments have moved together excluding the premaxilla.
This appearance of an intact arch is illusory; the segments merely abut one another.

Separation of the premaxilla from the lateral maxillary alveolar segments is what distinguishes a bilateral cleft lip and palate subject from all other cleft types. A BCLP subject presents with unique cleft characteristics, distinct from any other cleft lip/palate group. An understanding of the subsequent growth patterns of the premaxilla is crucial as it is thought by some to be the 'maxillary cornerstone', (Boo-Chai, 1971). Studies found that the premaxilla was protrusive inutero and kept protruding postnatally, (Latham, 1973). In other studies the post vomerine suture is thought to overgrow, sending the premaxilla forward in a horizontal direction, without an intact lip to restrain the overgrowth, (Friede, 1973; Berkowitz, 1996). There is great variation in the size and shape of the premaxilla. Some illustrations of the premaxillae in this study are shown in Figs. 6.6 - 6.13. Premaxillae can present as protrusive, rudimentary or totally absent, having been surgically resected! Rudimentary premaxillae present in varied forms but most present with no or few teeth. Subsequently minimal dental development of the rudimentary premaxilla occurs. Therefore in the rudimentary premaxilla some landmarks are missing for digitization viz. A point, AS, IS, Pr, see Fig.6.8. In these cases ANS may be the only distinguishable landmark. In this study all missing landmarks were digitized as null values and excluded from all analysis.

This study clearly demonstrates the multiple confounding factors experienced and the heterogeneity of this BCLP study sample. The varied presentation and nature of the protrusive, completely separate, independently mobile premaxilla further

complicates analysis. In the unoperated subject the premaxilla appears to be 'driven' forward, perhaps by the post vomerine suture, into a protrusive position. The anterior nasal spine in the unoperated (and operated subjects) is more superiorly and posteriorly placed, this can be seen Fig. 6.6. It would seem that the anterior nasal spine has not achieved a normal non-cleft position, irrespective of the protrusive premaxilla. The intrinsic malpositioning of the anterior nasal spine found in this study may influence any subsequent growth of the entire premaxilla within the maxillary relationship. The protrusion of the unoperated subject masks this underlying skeletal aberration. Henceforth any subsequent surgery to the lip or palate may correct the dental arch relationship but the anterior nasal spine remains in an incorrect skeletal position within the craniofacial complex. Illustrations of the varied premaxillary presentation and skeletal aberrations can be seen in Figs. 6.6 - 6.13.
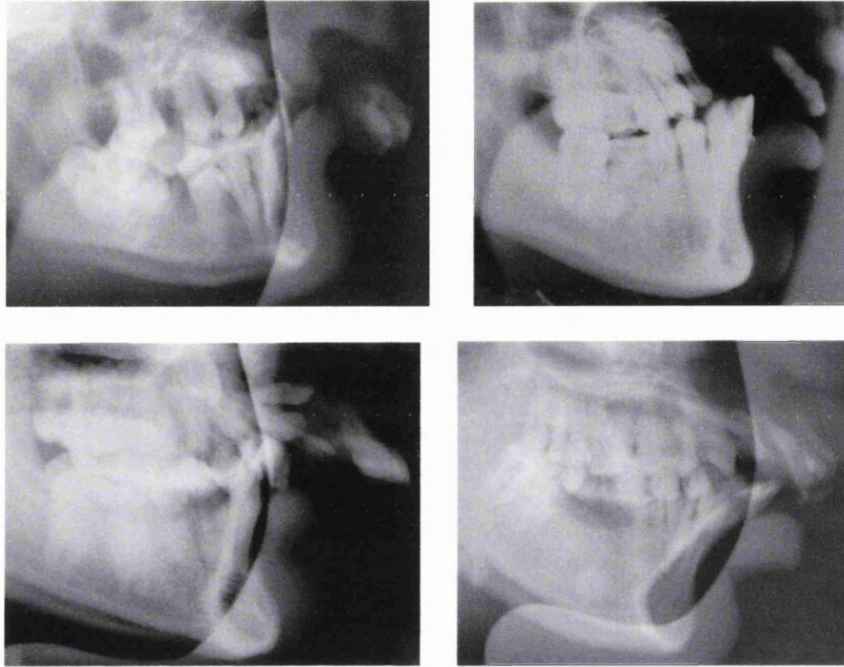
Fig. 6.6 Protrusive Premaxillae in the Unoperated Subject

Fig. 6.7 Normal Premaxillary relationship
(*After lip repair*)

Fig. 6.8 Rudimentary Premaxilla

Fig 6.9 Premaxillae highly impacted into the Nasal Cavity

Fig 6.10 Severely Retroclined Premaxilla   Fig 6.11 Premaxilla in severe overbite
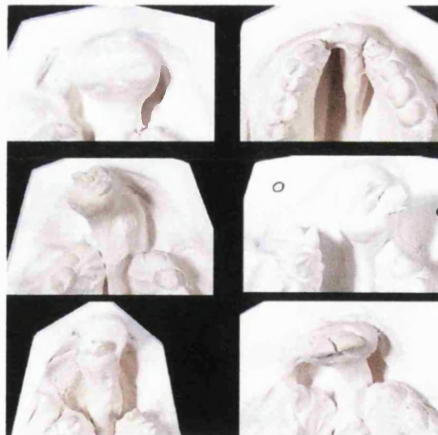
Fig 6.12 Surgically Resected Premaxilla   Fig 6.13 Varied Premaxillary Presentation

Some subject examples at different timings of surgical intervention can be seen in Chapter 3 Subjects and Methods Figs. 3.4 - 3.8 (Page 96 - 100).

Effect of Lip Repair

The cross-sectional and longitudinal data were analyzed to determine any effects of the lip repair on facial growth. The results showed that the reconstructed lip moulds the dentoalveolar segment of the premaxilla.

Hypothesis 2

Lip surgery has a moulding effect on the dentoalveolar component of the premaxilla. This does not cause maxillary retrusion.

This hypothesis is upheld. The protrusive premaxilla in the unoperated subject is unrestrained and independent from the lateral segments of the maxilla. After lip repair the reconstructed lip exerts a force onto the protruding premaxillary segment. Dentoalveolar moulding of the premaxillary segment is observed, retroclining the protrusive premaxilla. Separation of the premaxilla from the maxillary alveolar segments enables the reconstructed lip to mould the premaxillary segment post lip repair. All variables on the premaxillary segment showed a reduction in value post lip repair. This moulding is at the dentoalveolar level, as demonstrated by the maxillary protrusion variables. However, no change or effect on facial growth after lip repair was seen at the basal bony level. This dentoalveolar moulding of the premaxillary segment does not affect mid-facial growth and is not responsible for basal growth retardation.

Effect of palatal repair on facial growth.

Longitudinal analysis was used to determine any effects of the palate repair on facial growth at different timings of surgical intervention. Each individual subject expressed a slightly different growth pattern within the longitudinal follow up period. The overall growth pattern of the BCLP post palate repair subjects was found to be highly statistically different from the non-cleft Sri Lankan control population. In all nine facial growth areas (36 linear and angular cephalometric variables) statistically significant differences between the BCLP and Controls were observed.

Hypothesis 3

Surgery to the palate is potentially damaging to mid facial growth.

This hypothesis is upheld. Mid-face retrusion was observed in all post palatal surgery groups who underwent palatal surgery under the age of 18 years. This study's results shows that surgery does have a deleterious effect on the growth of the maxilla, leading to the severe mid-face retrusion seen in later life.

Hypothesis 4

Earlier palatal surgery is more damaging to mid facial growth than later surgery.

This study's results did not support this hypothesis. Mid-face retrusion was observed in all post palatal surgery groups under the age of 18 years. Surgery after puberty had little effect on mid-face retrusion. Deficiency of the antero-posterior and vertical growth in the maxilla and an excessive antero-posterior and vertical growth in the mandible enhanced the mid-face retrusion. No matter when surgery occurs before puberty, whether very early or during puberty, the same deleterious effects are shown. This study found that surgery at any time before pubertal growth has ceased could still result in a deleterious effect on mid-face growth. The age of palatal surgery made no difference to the facial growth outcome, therefore this hypothesis was not upheld. No evidence was found in this study that early surgery is more damaging than later surgery.

This study was embarked upon to test the hypothesis that surgery in some way is therefore responsible for the mid face retrusion that we see in so many of our own patients and in the operated Sri Lankan subjects. As an extension of this argument it seems reasonable to assert that the earlier the surgery to the palate was undertaken the more deleterious would be the effect on facial growth; and conversely if surgery is delayed we would expect to see better (less compromised) facial growth, (Hotz, 1969; Schweckendiek and Doz, 1978; Friede and Enemark, 2001). This is critically important because such philosophies have

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indeed been the justification for surgical techniques that delay surgery to the palate in the belief that this will minimize growth disorders. However the results of this study do not support this hypothesis and the concept of delayed hard palate surgery resulting in improved facial growth only applies when surgery is delayed well beyond the pubertal growth spurt over the age of 18-years. This study demonstrates that surgery undertaken at *any time* prior to the pubertal growth spurt has the same potential to disrupt mid facial growth whether in early infancy, 2.6 – 5 years, 5.1 – 10 years, or 10.1 – 18 years. Similar findings were highlighted in a mixed longitudinal Dutch study which examined the timing of hard palate closure and dental arch relationships in UCLP subjects, (Noverraz et al., 1993). It would seem this finding could have significant implications for the clinical management of these patients. If surgery is deleterious to facial growth if undertaken anytime before puberty is completed and if early palatal surgery is necessary for speech development then there is no justification for delaying palatal surgery. Rather, our efforts should be directed at the *nature* of surgical intervention as a factor possibly affecting the facial growth outcome rather than the timing.

The reason why some authorities believe that delayed hard palate repair is less damaging to palatal growth is that the subjects were not followed up throughout their entire facial growth period, after adolescence and into adulthood. The final

facial growth outcome only becomes apparent during and after puberty, at the cessation of facial growth.

The extreme arguments are true: early surgery has been shown to cause mid-face growth disturbance and normal growth or an overgrowth of the maxilla is seen in the totally unoperated subject. People were led to believe that in some way operating in the middle of these two extremes would result in only half the disruption to facial growth, reducing the time for the deleterious effects on facial growth. It is the increased acceleration of facial growth during the pubertal growth spurt that magnifies the iatrogenic deformity.

The separate and combined contribution of Intrinsic and Iatrogenic facial growth disturbances affecting eventual outcome.

Both intrinsic and iatrogenic deformities were found within the study results. Intrinsic cleft features were discovered when this sample was compared to a non - cleft Sri Lankan population. Iatrogenic deformities were discovered when an altered effect on growth was observed after surgical intervention.

The cranial base measures are considered by many not to be directly affected by the cleft deformity but more perhaps a part of an inherent cleft skeletal growth pattern, (Ross, 1987a; Filho et al., 1996; Filho et al., 1998). While other authors found no difference between the cleft and non-cleft groups, (Bishara et al., 1978). In this study the cranial base was found to be smaller in both linear and

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angular dimensions. This was an intrinsic cleft deformity. These statistically significant differences highlight an underlying intrinsically different skeletal pattern in the BCLP subject when compared to the controls, irrespective of the age at surgical intervention. Further, it would seem that the landmark Basion in this BCLP sample was more superiorly and anteriorly placed than in the non-cleft Sri Lankan population (controls) in relation to other cranial base measures and surrounding anatomical structures. The implication of an altered cranial base measure can affect all facial growth parameters, as the cranial base is used as the reference point for many of the facial growth parameters.

The unoperated subjects demonstrated severely protrusive premaxillae. The underlying intrinsic growth pattern for the unoperated subject would seem to present with a protruding premaxillary segment with no structure to impair its movement. The severely retrognathic positioning of the anterior nasal spine was a very interesting finding and contrary to the clinical impression of prognathism. Coupled with the mal-position of the pterygo-maxillary fissure it would seem logical to assert that the overall positioning of the maxilla is very different than in the non-cleft population. These findings are primarily intrinsic cleft deformities, however some iatrogenic deformities were also observed in the maxillary protrusion.

These findings concur with earlier studies in UCLP that showed subjects who have not received palatal surgery to demonstrate good maxillary growth during

puberty, (Mars, 1993;   Muthusamy, 1998;   Arshad, 1998;   Chia, 1999;   Aker, 2001).

In conclusion the Maxilla exhibits an overgrowth or normal palatal length but is posteriorly placed within the craniofacial complex. Deficiency in anteroposterior and vertical growth of the Maxilla coupled with an excessive anteroposterior and vertical growth of the mandible heightens the appearance of the mid-face retrusion and resultant concave facial profile.

Furthermore another important finding of this study is that adequate dental arch relationships can be achieved with palatal surgery under the age of 18-years. However, the whole maxillary/mandibular relationship is malpositioned within the craniofacial complex. The underlying skeletal position of the maxilla is posteriorly placed, while the mandible exhibited an overgrowth in both linear and vertical dimensions. However these 'intrinsic' features could also be a manifestation of developmental distortion, abnormal muscle exertion over time. Nevertheless, good dental arch relationships are still possible within a deformed skeletal configuration of the maxilla and mandible. Examples of these findings can be seen in Figs. 3.4 - 3.7 (Page 96 - 99).

In Conclusion the Intrinsic and Iatrogenic deformities found in this study are:

Cranial Base	Smaller in both linear and angular dimensions. Basion mal-positioned	Intrinsic
Maxillary Protrusion	Prominent Premaxilla in Unoperated & PostLip Ans & Ptm mal-positioned	Intrinsic Iatrogenic
Maxillary Length	Palatal Length was longer in Unoperated. Normal length in PostLip & PostPal groups.	Intrinsic Iatrogenic
Maxillary/Mandibular Dimensions	Facial Convexity Angle is decreased, highlighting a retrognathic mandible.	Intrinsic
Mandibular Protrusion	Normal Mandibular Protrusion angles in all groups.	Intrinsic
Mandibular Dimensions	Increase in Ramus and Mandibular Body length. Increase in Gonial Angle.	Intrinsic
Facial Heights	Normal Upper Anterior and Posterior heights. Increased Lower and Total Anterior Facial height.	Intrinsic
Incisor Relations	Reduced Upper and Lower incisal angles. Increased interincisal angle.	Intrinsic Iatrogenic

Intrinsic features of facial growth and morphology are demonstrated in both the unoperated and operated groups.

Iatrogenic features are demonstrated in the post palatal surgery.

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Not all facial growth deformity can be attributed to either an intrinsic or iatrogenic deformity, many other factors can contribute to how an individual grows: -

So far some justification for the disturbance to facial growth has been discussed, however another factor that can affect the facial growth outcome may be the surgeons' ability, (Williams et al., 1994; Williams et al., 2001). The nature and timing of the surgery and also the skill and competence of the surgeon may affect the resultant facial growth outcome. Many factors may have an effect: the presence of scar tissue, operating too near to the sphenooccipital synchondrosis, the cranial base growth centre, each individuals' growth response or nutritional, psychological and environmental factors involving the persisting deformity of an unoperated cleft.

In this study the surgeons involved were the premier cleft lip and palate surgeons at the time, with considerable cleft experience. However in the Western world the timing of the lip and palate surgery may have been different. The conventional surgical protocol would have been lip repair with a vomer flap at 3 months followed by palate repair at 6 months. The surgeons on this project were not able to work to their normal protocols. The lip and palate was closed when the subject attended the British Team's joint clinic. Therefore, the surgeons were working on older patients, with wider clefts and in bilateral cases were not able to perform vomer flaps routinely. Pre-surgical orthopaedics to aid arch alignment prior to lip

closure was not undertaken. These complications of operating techniques may also have had an impact on the resulting facial growth outcome.

The majority of craniofacial growth postnatally is in the dentofacial region. The vertical height of the maxilla in the tuberosity region is only evident after the translocation of the Maxilla. This downward forward movement of the Maxilla occurs with the nasal and oral vertical growth period. In the Figure 6.16 & 6.18 the newborn infant presents with an absence of any tuberosity region whilst in figure 6.15 & 6.17 the posterior vertical growth of the Maxilla and its interrelationship to the surrounding craniofacial structures is illustrated. In addition, the area at which the palatal surgery is performed is in close approximation to the sphenooccipital synchondrosis and the medial and lateral pterygoid muscles, as seen in figure 6.19. Interference with the key palatal growth centres is likely to alter the 'blueprint' for the maxillary facial growth pattern, a 'blueprint' of an intrinsically preprogrammed 'cleft' growth pattern might be hypothesized. It might be suggested that a combination of surgical disruption and a preprogrammed intrinsic cleft growth disturbance may explain such vast statistical differences between the BCLP subjects and Sri Lankan Control population.

A common finding in the West a bilateral fibrous band is a frequent clinical observation in the repaired cleft lip and palate subject. The scar tissue bands run down from the hamulus downwards and laterally to the medial surface of the

Fig 6.15 Adult Skull

Fig 6.16 Newborn Unoperated UCLP Skull

Fig 6.17 Adult Skull
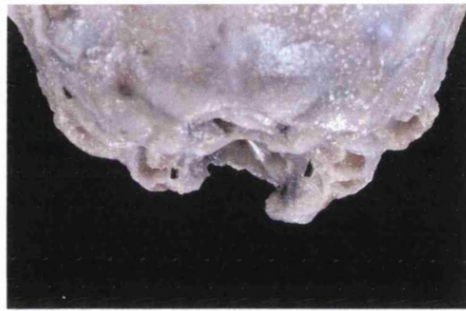
Fig 6.18 Newborn Unoperated UCLP Skull

Fig 6.19 Newborn Unoperated UCLP Skull

The Professor of Forensic Medicine in Sri Lanka gave the newborn unoperated UCLP specimen to Dr Mars. The facial growth attributes discussed are not meant as a direct comparison between a newborn unoperated subject and an adult non-cleft specimen. The observations discussed in these photographs illustrate the inherent underlying skeletal differences that exist in the newborn infant and the mature adult.
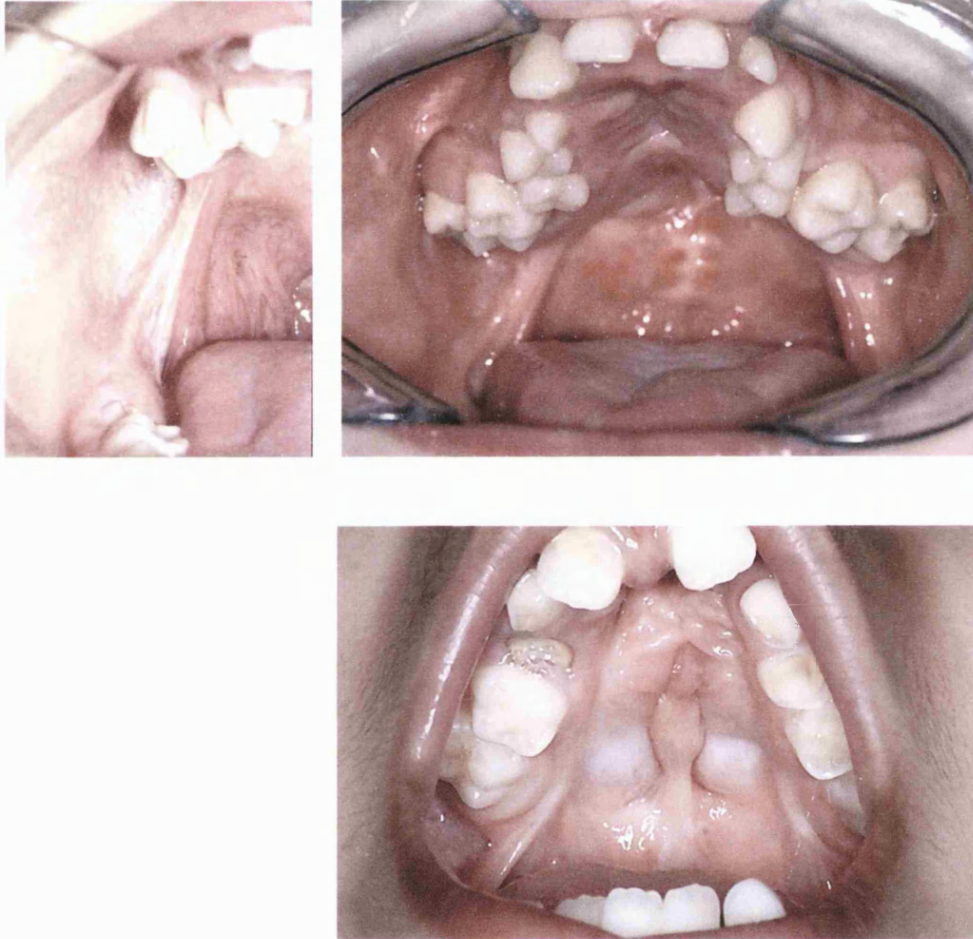
Fig 6.20 Scar Tissue Bands
Scar tissue bands may cause transverse palatal contraction and may reduce posterior facial heights.

mandibular ramus in the retromolar region, along the course of the medial and lateral pterygoid muscle. The contraction of these soft tissue bands may explain the reduction or inhibition of growth to the lower posterior facial height. Some examples of this fibrous scar tissue can be seen in Fig.6.20. The surgical technique of palatal closure itself may also cause an iatrogenic deformity or at best interfere in the facial growth process. In this study all of the BCLP subjects had "invasive" von Langenbeck palate repairs. The von Langenbeck surgical technique necessitates the raising of large mucosal flaps to close the palatal cleft. This technique leaves raw areas on each side of the palate, which is left to epithelialise, forming scar tissue; this scar tissue is considered to restrict growth. Use of a vomer flap at the lip repair would have already closed the anterior region of the cleft palate. The remaining hard palate closure would therefore be smaller and less invasive, minimizing the disruption to the muscles, mucosa and blood supply: Reducing the invasive nature of the palatal surgery minimizes the resultant scar tissue formation, thereby decreasing the facial growth interference. However such scar tissue formation using the von Langenbeck technique, especially in conjunction with the vomer flap, is much less invasive than the previously popular Veau-Wardill-Kilner 'pushback' procedure. This *nature* of surgical intervention should be considered as a factor affecting facial growth in further investigations of facial growth outcome rather than the timing.

Psychosocial and Environmental Factors

Puberty is delayed in the Sri Lankan and other rural populations in the developing world, (Fernando et al., 2000) (see Chapter 2 Literature Review). Socio-economic status, nutritional status and family support influence the physical and emotional development of children, (Brook, 1995). Most of the BCLP subjects in this study were from a low socio-economic background. The Control population used in for this study comprised equal numbers of rural and urban subjects to achieve a representative spread of the Sri Lankan socio-economic variances within the same population. It should also be noted that the non-cleft Sri Lankan population was in general less well developed, compared to Caucasian children of similar chronological age, (Mars, 1993). This has huge implications when comparing the results of this study with the results of studies using subjects from different ethnic groups and socio-economic backgrounds.

In the Human Development Index Table 2.1 in Chapter 2 Literature Review it can be seen that malnutrition is still prevalent in Sri Lanka. Low birth weights, and low heights for age are still a problem. In this sample of BCLP subjects feeding problems exist. There was no cleft team structure to assist and educate in feeding techniques or nutritional supplements. It is likely therefore that a low birth weight baby may then become malnourished leading to a low weight for age and low height for age. The phenomena of catch up growth is well documented but if the necessary supplements are not available to re-dress the balance then the

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cycle of malnutrition continues. In Sri Lanka few programmes provide nutritional supplements, (Rajapaksha and Siriwardena, 2000).

In a recent review of the medical notes on the Sri Lankan cleft lip and palate project it was found that 50% of parents/subjects had no idea as to the aetiology of their cleft lip and palate, while 34% believed that a curse or bad karma from a past life predetermined their deformity. In the Projects' experience many of the cleft subjects have never married, only one of the mature BCLP subjects married. Very few subjects completed all the school years and most subjects had poorly paid jobs, if a job at all. Poor intelligibility of speech made communication very difficult and many were teased or bullied at school.

This study has shown statistically significant differences between the control population and the BCLP subjects at the start of treatment. In most facial growth variables the study subjects were found to be smaller and shorter than their non-cleft counterparts. Equally the BCLP subjects height SDS found the cohort to be within the lower limits of the normal range for age when compared with the control population, see Figs.4.7, 4.8 & 4.9. After lip repair and subsequent palate repair the increase in facial growth parameters observed was found to be highly significant. The steep increase in growth with age from negative SDS to an even higher SDS than the control population is dramatic. The mean growth velocity distribution for the Control's would feature as a straight line at or around the 50th percentile or the population mean of 0, as a SDS, throughout puberty. The steep

growth velocity observed and the amount of growth coefficient is hard to explain. One explanation may be that the surgical intervention and anatomical repositioning of structures then creates the correct climate to grow but more likely, this growth could be representative of the catch-up growth phenomena. This could be associated with better feeding post operatively having had their cleft lip and palate repaired improving oral function. Another explanation could be that with improved feeding the level of nutrition might be improved and instigate growth hormone secretion. Any improvement in self-esteem and self worth might be associated with a change in the psychosocial and environmental factors, which can often be associated with psychosocial dwarfism.

Psychosocial dwarfism and emotional deprivation has a profound influence on the growth process and may interact with the provision of food, (Brook, 1995). A child with good marriage and job prospects may be given more love and be nurtured more than a child with fewer life prospects and such a child may be seen as a burden of care to the family. The social stigma of a cleft as a curse or bad karma reflects not only on the family but also on the village. Children need a good emotional climate in which to thrive. The mechanism of the effects of emotional deprivation on growth is not well documented but is linked to reduced growth hormone secretion and associated growth failure. The physical and mental well being of a child is related to the psychological and emotional environment in which they are reared. Psychosocial and nutritional dwarfism are

characterised by poor linear growth and delayed pubertal development, (Green et al., 1984; Sandberg et al., 1991). Malnutrition and emotional stress can cause endocrine abnormalities, producing high levels of cortisol secretion, which has a growth-retarding effect. Lack of love, or an adverse emotional or social environment can cause growth failure in a child who is well nourished. '*However, any growth failure or endocrine abnormalities that occur in a child can cause growth-retarding effects*'. This condition called Psychosocial dwarfism does not respond to growth hormone treatment but once the child is placed in an alternative environment the effects are reversed and rapid 'catch-up' growth takes place, (Stanhope et al., 1994). In his study, after a period of hospitalisation some 'catch-up' growth could be seen.

It can reasonably be surmised that this BCLP cohort has experienced both psychosocial dwarfism and nutritional deficiencies. (Habel, 2003) The effect of such a persisting deformity, as an unoperated or operated cleft lip and palate, which worsens their appearance or speech throughout their life places a considerable burden of care on their families. However, vast improvement in self-esteem and self-worth was evident among the subjects in this project after surgical closure of their cleft lip and palate. Each individual subject to a greater or lesser extent has expressed 'catch-up' growth post surgery. This may be one explanation of such statistically different increases in facial growth velocity seen among these subjects.

Dental Caries

Another devastating problem that is still prevalent is dental caries within the Sri Lankan population. The poor diet and lack of access to good food causes people to eat sugar in large quantities for essential calorie intake. Protein, fresh fruit and vegetables are expensive. The national per capita annual income is $780. Inflation has caused price rises while the Rupee has devalued; in 1984 £1 = 50 R in 2003 £1 = 150 R. For the unemployed and low socio-economic groups the devaluation of the Rupee means the poor are getting poorer. Until recently the civil unrest in the North and East of Sri Lanka had crippled the country economically. It can only be hoped that in peace, the transport, medical and economic infra structures within Sri Lanka can start to be rebuilt. One example of the severe dental caries experienced in Sri Lanka can be seen in Fig. 6.21. This unoperated subject, aged 6, required a total dental clearance due to his caries prior to his cleft lip and palate repair.

The reconstructed lip, retroclining the premaxillary segment within the dental arch, moulds the premaxilla. Loss or decay of the upper incisal teeth, which help to stabilise the independently mobile premaxilla jeopardises the whole stability of the premaxillary segment, as seen in Figs. 6.22 & 6.23. The good early premaxillary relationship in both these subjects helped maintain a good dental arch relationship and good underlying skeletal pattern. However, after the loss of the upper anterior teeth (because of caries) the unstable premaxilla is not held forwards by the occlusion of the incisors and 'collapses'. This loss of support

anteriorly worsened the concave skeletal profile. Many other subjects have very few teeth left, due to bad oral hygiene and a poor diet. This edentulism further exacerbates this type of facial collapse. The tendency toward a Class III malocclusion, with over compensation of the mandible to achieve closure exaggerates the concave facial profile.
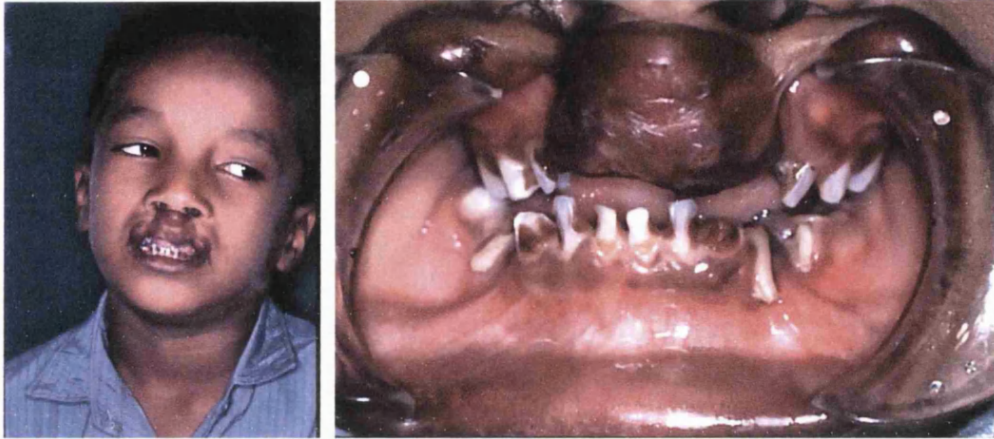
Fig 6.21 Prevalent Dental Caries in Sri Lanka

Fig 6.22 Examples of compromised facial growth due in part to Dental Caries

Age 9   Age 9   Age 10   Age 12

Age 14   Age 19   Age 26   Age 26
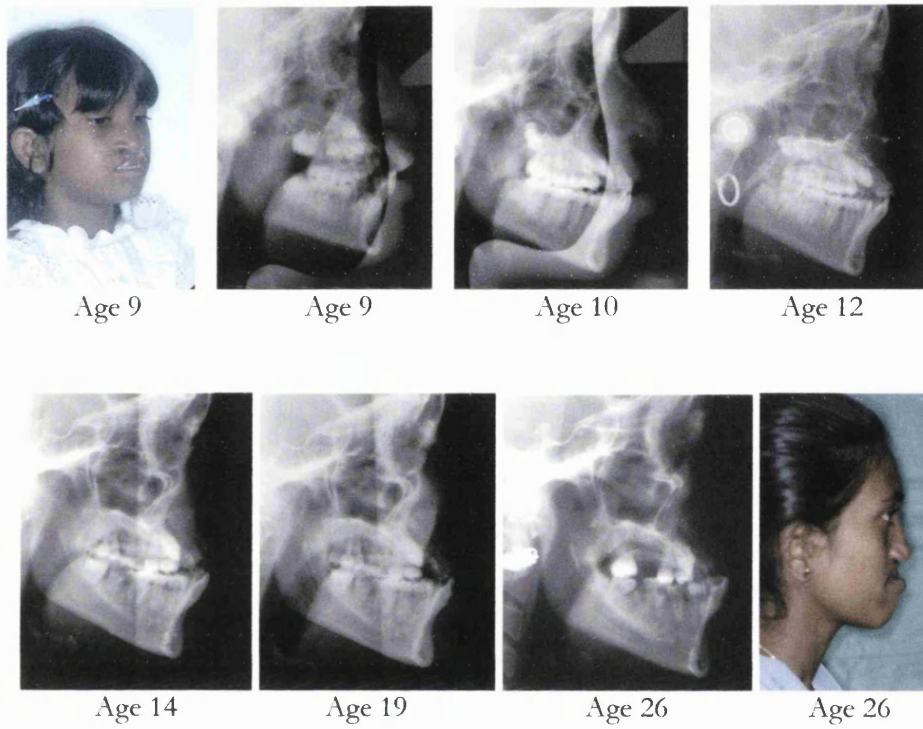
Fig 6.23 Dental Study Models Aged 9, 10 &12.
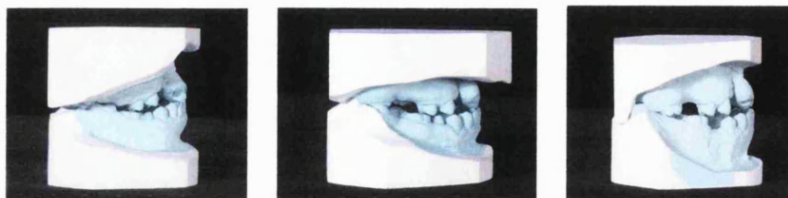
Fig 6.24 Dental Study Models Aged14, 19 & 26.
Premaxillary collapse due to loss of anterior retention by the upper incisors due to dental caries.

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Fig 6.23 Examples of facial growth compounded by the loss of the upper anterior teeth

| Post Lip Repair | Post Palate Repair | Post Palate Repair |
| Age 13 | Age18 | Age25 |

| Age 13 | Age18 | Age25 |
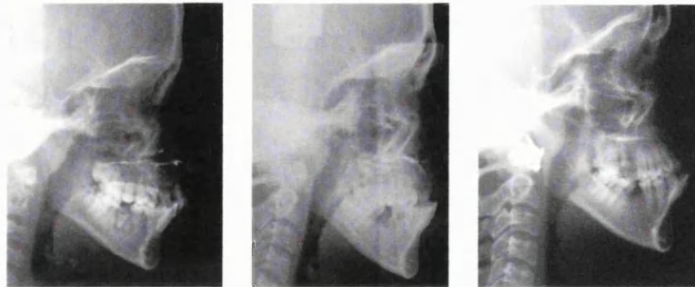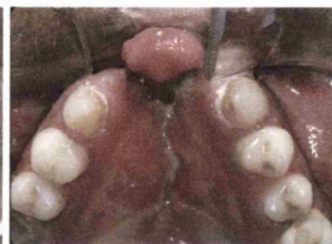
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Over the 18-year surgical and longitudinal data collection periods the recall rate for the BCLP sample has been staggering. In the last data collection visit, October 2002, the recall rate for the bilateral subjects was 79%. Many of the BCLP sample have poor speech. This may be due mainly to a delayed palate repair or in addition the presence of anterior fistulae. There is evidence that palatal surgery after the age of 8 years results in poor speech outcomes and glottal articulation, (Sell, 1991). Until five years ago there was no speech and language therapy available in Sri Lanka for a population of 18 million; there was 1 part-time therapist who worked in the private sector. Their poor speech, inability to communicate and suffering assoiciated psychological effects seriously compromised many of these subjects. Equally five years ago there was no orthodontic provision in Galle, for the general public, only the private sector.

All of the BCLP subjects need orthodontic treatment prior to alveolar bone grafts to immobilise the premaxillary segment. Many require orthognathic surgery to correct the mid-face retrusion. The very high recall rate after surgical intervention may in fact be a manifestation of how unhappy these subjects are with their appearance. The initial primary cleft lip and palate surgery transformed their lives and helped them function as more normal human beings within their society but with subsequent facial growth their appearances have worsened.

Ethical Approval and Informed Consent

Good research should be well justified, well planned, appropriately designed and ethically approved. To conduct research to a lower standard may constitute misconduct. (World Health Org., 2002) Whenever medical research involves human subjects the known benefits, risks or disadvantages of the treatment must be explained to the study subjects. An exact description of the treatment protocol must be delivered to the subjects both orally and in writing (World Medical Assembly, 1964; World Health Org., 1977).

The use of ionising radiation in human subjects has been the subject of specific recommendations particularly from the World Health Organization. The exposure of humans for medical research is not justified unless it is in accordance with the provisions of the Helsinki Declaration, (World Medical Assembly, 1964). In this report it states that medical research should conform to scientific principles, with appropriate caution and contain a statement of the ethical considerations involved. For all biomedical research involving human subjects, the investigator must obtain the informed consent of the prospective subject. Informed consent contains three elements: information, comprehension and voluntariness.

In this study formal ethical approval was only obtained in 1990, previously all radiographs were treatment related. In recent years the justification for non-treatment related radiographs for subjects and for Controls has been

questioned. There are increased risks assoiciated with ionising radiation, (DoH, 2000) however ethical approval was obtained from both the University of Ruhuna, Galle, Sri Lanka and through the Research & Development Office in the Institute of Child Health, University of London. Verbal agreement for the longitudinal record collection, including radiographs was obtained. The risk assessment of a skull radiograph with an effective dose of 100 μSv is considered to be 'minimal' for developing an adverse response (Smart et al., 2003). Nevertheless, it is interesting to consider that such ethical approval in the future may not be granted for any similar study. It is also interesting to note that perhaps the most famous longitudinal study in cleft lip and palate relied on lateral skull radiographs taken annually for a series of several hundred patients, (Semb, 1991). In Semb's study the radiographs were collected from earlier decades and considered 'ethical' in regard to informed consent and ethical approval for radiographs at the time.

In summary this study re-confirms the results of other studies on facial growth in cleft lip and palate, showing relatively normal facial growth in the unoperated subject and disruption to facial growth in the operated subject. However, this unique longitudinal study of BCLP subjects over an 18-year follow-up has revealed some surprising, interesting and counter-intuitive results. Previous studies have not had the benefit of longitudinal growth records over such a long follow-up period. Perhaps the most important result in this context is that palatal surgery undertaken at any age before the pubertal growth spurt can be severely damaging to this period of rapid acceleration of growth resulting in stunting of the maxilla. The plethora of studies suggesting that the later the surgical intervention is undertaken the better the outcome, is seriously challenged by this PhD study. Further, the clinical implication that delayed hard palate closure is of benefit to facial growth is also therefore challenged. The philosophy of delayed hard palate closure has gained extensive popularity but has been based on flawed retrospective analysis in which subjects are not examined beyond puberty. Growth of the mid-face, in part, is the translocation of the maxilla downwards and forwards from the cranial base, this phenomenon, which is mainly expressed in puberty, accounts for the radical change in facial appearance from infancy to adulthood. Such growth is minimal before puberty. This study confirms the arguments previously suggested

by others, which suggest no benefit of delaying the hard palate repair from a facial growth perspective, (Witzel et al., 1984; Ross, 1987d; Noverraz et al., 1993). Our efforts should be directed at the nature of surgical intervention as a factor possibly affecting the facial growth, rather than the timing of that surgery.

A combination of multiple confounding factors: intrinsic and iatrogenic features, malnutrition, psychosocial dwarfism, dental caries, surgical technique, abnormal growth of both the maxilla and mandible and their relation to the cranial base, were experienced in this study.

It is the cumulative effect of the multiple variables in mid-face retrusion, which would benefit from orthognathic surgical correction. Isolated differences may be small but the summation of all the different changes in craniofacial parameters is clinically and statistically highly significant.

Chapter 7

FURTHER INVESTIGATIONS

Further research on the Sri Lankan bilateral cleft lip and palate subject could be achieved by additional data collection visits until each post operative subject is over the age of 25 years and could be considered post pubertal. In this series the last data collection visit to fulfil this objective would be in the year 2010; further records on 36 males and 13 females would be required to achieve full post pubertal growth records on this BCLP sample.

Collecting the study models and lateral skull radiographs of more unoperated BCLP subjects and their subsequent growth would improve sample sizes. The pool of older unoperated BCLP subjects in Sri Lanka is reducing rapidly because of an improved provision of surgical care. However this study is one of the world's largest in BCLP to date.

Further investigation into the effect of surgery on the premaxillary segment could be examined with a reflex microscope on the dental study model archive. The minutiae of movements and the dentoalveolar moulding effect by lip repair could be examined.

Appendix A

Statistical Analysis for the Longitudinal Results

Three questions were quantified:

1   The overall mean variable.

2   What happens with growth – the slope of the regression line?

3   What is the effect of the age at operation on the variable value – does the slope change according to the age at palate repair?

Multiple Linear Regression

Question	1	2	3
Ba_N			
Coeff.	-1.12	0.16	-0.01
t ratio	-9.36	9.19	-2.82
P value	0.0001	0.0001	0.006
S_N			
Coeff.	-0.10	0.08	-0.0003
t ratio	-1.09	7.54	0.11
P value	0.28	0.0001	0.91
Ba_S			
Coeff.	-2.07	0.1512	-0.0196
t ratio	-15.7	5.714	-2.971
P value	0.0001	0.0001	0.0039
BaSN			
Coeff.	0.4	-0.004	-0.03
t ratio	4.17	0.37	-1.16
P value	0.0001	0.72	0.25

	1	2	3
SNA			
Coeff.	-0.1	-0.13	-0.0003
t ratio	-0.66	-6.7	0.052
P value	0.51	0.0001	0.96
SNAS			
Coeff.	0.09	-0.17	0.004
t ratio	0.58	-8.4	0.54
P value	0.56	0.0001	0.59
SNIS			
Coeff.	-1.88	-0.06	0.003
t ratio	-9.95	-3.74	0.47
P value	0.0001	0.0004	0.64
SNPr			
Coeff.	-1.01	0.13	0.003
t ratio	-5.8	-9.63	0.65
P value	0.0001	0.0001	0.52
SNAns			
Coeff.	-8.99	0.38	-0.026
t ratio	-49.1	14.55	-3.73
P value	-0.0001	0.0001	0.0004
NSPtm			
Coeff.	0.43	0.017	-0.004
t ratio	5.01	1.29	-1.15
P value	0.0001	0.20	0.25
Ba_Ptm			
Coeff.	-1.63	0.11	-0.01
t ratio	-14.91	5.47	-2.55
P value	0.0001	0.0001	0.013
Ar_Ptm			
Coeff.	0.77	0.040	-0.0004
t ratio	-7.46	2.38	-0.097
P value	0.0001	0.02	0.92
Ans_Ptm			
Coeff.	0.31	-0.054	-0.005
t ratio	2.39	0.024	-0.69
P value	0.02	0.029	0.49

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	1	2	3
Ar_Ans			
Coeff.	-0.28	-0.002	-0.001
t ratio	-2.34	-0.09	-0.21
P value	0.021	0.93	0.83
Ar_A			
Coeff.	-0.20	-0.006	-0.004
t ratio	-1.59	-0.26	0.57
P value	0.11	0.78	0.57
NaPg			
Coeff.	-8.73	-0.12	-0.0003
t ratio	-76.18	-10.09	-0.08
P value	0.0001	0.0001	0.94
SNII			
Coeff.	-0.96	-0.05	0.001
t ratio	-8.37	-4.44	0.40
P value	0.0001	0.0001	0.69
SNID			
Coeff.	-0.25	0.08	-0.009
t ratio	-1.93	6.68	-2.81
P value	0.06	0.0001	0.006
SNB			
Coeff.	-0.19	0.07	-0.007
t ratio	-1.59	6.16	-2.52
P value	0.11	0.0001	0.014
SNPg			
Coeff.	-0.01	0.08	-0.007
t ratio	-0.09	7.17	-2.24
P value	0.93	0.0001	0.03
Ar_TGO			
Coeff.	0.29	0.24	-0.01
t ratio	2.06	17.58	-2.93
P value	0.04	0.0001	0.005
TGO_Gn			
Coeff.	0.52	0.27	-0.016
t ratio	3.91	15.02	-3.42
P value	0.0001	0.0001	0.001

	1	2	3
ArTGOGn			
Coeff.	0.62	-0.05	0.003
t ratio	6.05	-3.71	0.81
P value	0.0001	0.0004	0.43
Ar_Pg			
Coeff.	0.69	0.38	-0.02
t ratio	3.95	19.95	-4.45
P value	0.0001	0.0001	0.0001
Ar_B			
Coeff.	0.33	0.31	-0.018
t ratio	2.04	17.2	-3.9
P value	0.04	0.0001	0.0002
S_N_Ans			
Coeff.	0.27	0.25	-0.019
t ratio	1.62	8.32	-2.27
P value	0.11	0.0001	0.03
TGO_Gn_Ans			
Coeff.	0.88	0.21	-0.002
t ratio	5.24	10.03	-0.4
P value	0.0001	0.0001	0.69
Ptm_Ans_Gn			
Coeff.	1.06	0.29	-0.002
t ratio	5.65	12.31	-0.25
P value	0.0001	0.0001	0.81
N_S_Ptm			
Coeff.	-0.21	0.18	-0.01
t ratio	-1.6	8.56	-2.27
P value	0.11	0.0001	0.03
N_S_TGO			
Coeff.	0.18	0.27	-0.01
t ratio	1.21	19.19	-3.13
P value	0.23	0.0001	0.002
S_N_Gn			
Coeff.	0.88	0.41	-0.01
t ratio	4.55	19.6	-2.56
P value	0.0001	0.0001	0.01

	1	2	3
Gn_MT1.Ptm_Ans			
Coeff.	0.45	-0.07	0.0004
t ratio	3.65	-3.32	0.67
P value	0.0004	0.001	0.51
Gn_MT1.N_S			
Coeff.	0.41	-0.04	0.006
t ratio	3.75	-3.01	1.85
P value	0.0003	0.004	0.07
S_N.AS_IS			
Coeff.	-3.17	0.19	-0.018
t ratio	-9.98	3.33	-0.98
P value	0.0001	0.001	0.33
II_AI.Gn_MT1			
Coeff.	-1.72	-0.037	-0.001
t ratio	-16.92	-2.91	-0.34
P value	0.0001	0.005	0.74
AS_IS.II_AI			
Coeff.	3.01	-0.07	0.02
t ratio	13.94	-3.16	1.93
P value	0.0001	0.002	0.06

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Konica

PhD Thesis Graphs

700MB

BCLPSDS - Cross-sectional data
BCLPSDSangles - Longitudinal data
BCLPSDSlinear - Longitudinal data