DENTO-FACIAL CHANGES DURING STAGE 1 ORTHODONTIC TREATMENT WITH THE BEGG APPLIANCE

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the degree of Master of Dental Surgery

by

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SUMMARY

The present study observed the dento-facial changes of Class II division 1 malocclusion patients treated by Begg appliance from pre-treatment until stage 1.

All of the 85 patients displayed Class II division 1 malocclusions and were treated with the Begg appliance in the Orthodontic Post-graduate Course at the University of Adelaide. The female patients were aged between 10.5 to 16.0 years, and the males between 12.2 to 15.5 years. The average age of subjects was 13.6 years, implying that some would have experienced their adolescent growth spurt during the treatment period and therefore some of the observed changes were related to rapid growth superimposed on treatment effects.

The sample was divided into 15 male-extraction, 17 male-nonextraction, 29 female-extraction, and 24 female-nonextraction groups according to the type of treatment performed. Each was further subdivided according to face type by using the ratio of the posterior face height to the total anterior face height.

The cephalometric analysis was completed with care and caution. The data were transferred by electronic digitizer in association with a program for computerized cephalometry. All measurements were adjusted to allow for radiographic enlargement (8.8%). Some points located on a smooth curve, such as, superior labial sulcus (sls), soft tissue pogonion (pos), pogonion (pog), displayed significant errors along the y-axis. The images of landmarks of the molar teeth on the lateral cephalograms were also poorly resolved and made determination of their positions difficult. This caused all of the variables that involved the molar teeth and the occlusal planes to be associated with relatively large errors in location.

Basic descriptive statistics were computed for all variables to summarize the data, and ANOVA was used to compare the mean values between groups. Correlation analysis quantified the strength of the association between each variable to the face type (long, average, and short face types).

Many pre-treatment variables showed statistically significant differences at $p < 0.05$ level between males and females, for example :

- the angle of the lower incisor to the mandibular plane was more proclined in females than in males;
- the perpendicular distance from the lower incisal edge to the mandibular plane was larger in males than in females;
- overbite was deeper in males than in females;
- maxillary and mandibular length was longer in males than in females;
- upper anterior face height and total anterior face height were longer in males than in females;

- the distance from the tip of nose to the soft tissue chin was longer in males than in females;

- the hard tissue chin point along y-axis, pogonion (pog-y), was longer in males than in females;

- the distance from the lower lip, sll, along the y-axis was longer in males than in females.

This indicates that males have a facial skeletal size larger than females, and also that the lower incisors in males are less proclined than in females. Although the ages of males and females in the present study were quite similar and normally females in this age are close to adult size, males still showed a larger cranio-facial skeleton size.

Male-extraction and male-nonextraction groups showed statistically significant differences at $p<0.05$ for the following pre-treatment variables :

- upper incisor inclination in the male-extraction group was more proclined than in the male-nonextraction group;

- the nasolabial angle in the male-extraction group was more obtuse than in the male-nonextraction group. However, the nasolabial angle was one of the variables that showed relatively large errors;

- the interlabial gap in the male-extraction group was larger than in the male-nonextraction group.

Female-extraction and female-nonextraction groups showed statistically significant differences at $p<0.05$ level for the following pre-treatment variables:

- the inclination of the lower incisor to mandibular plane in the female-extraction group was more proclined than in the female-nonextraction group;

- mandibular length (co-gn) in the female-extraction group was shorter than in the female-nonextraction group.

Treatment from banding until the end of stage 1 produced a reduction of the interlabial gap in both male-extraction and female-extraction groups. This was statistically significant at $p<0.05$ level only in the male-extraction group where the interlabial gap was reduced by an average of 2.72 mm. The relatively large variation in interlabial gap reduction between individuals (sd = 2.2mm) may have been partly due to some patients not having their lips completely relaxed at the time when the radiographs were taken.

Patients were divided into groups according to their face type by using the ratio of the posterior face height to total anterior face height. This ratio was low in long-faced patients, and high in short-faced patients. Correlation analysis was then used to quantify the strength of association between the change of each variable with face type. The results of this analysis showed that in the male-nonextraction group, the change of the perpendicular distance from lower incisal edge to mandibular plane was negatively correlated ($r = -0.66$) with the face height ratio. This indicates that long-faced patients tended to display a greater change in this variable than short-faced patients.

In the male-extraction group, the steepness of the mandibular plane angle to sn plane had a significant negative correlation (r = -0.65) with face height ratio. This indicates that long-faced patients, who normally have steep mandibular plane angles, tended to have more mandibular plane opening than short-faced patients from pre-treatment until stage 1 in Begg treatment technique. The change in posterior face height showed a positive correlation with face height ratio. This indicated that long-faced patients tended to have a smaller increase in the posterior face height than short-faced patients.

In the female-nonextraction group, the change in the ratio of posterior face height to total anterior face height, the change of the perpendicular distance from lower incisal edge to mandibular plane, and the change of the nasolabial angle, all showed negative correlations with face height ratio. This means that long-faced patients tended to have a smaller increase in posterior face height or a greater increase in the anterior face height than short-faced patients. On the other hand, short-faced patients had a larger increase in posterior face height and smaller increase in the anterior face height than long-faced patients. The nasolabial angle in long faced-patients was larger, and had a greater increase due to treatment than occurred in short-faced patients.

In the female-extraction group, the steepness of maxillary plane showed a significant negative correlation (r = -0.43) with the face height ratio. This means that long-faced patients tended to show greater change in the steepness of the maxillary plane than short-faced patients.

The Begg treatment technique during stage 1 also produced a reduction in the interlabial gap in the male-extraction patients in the present study. Males and females showed statistically significant differences in some variables, especially skeletal size. The different treatment groups, extraction and nonextraction, also responded differently to treatment. The results from correlation analysis indicated that the treatment responses of some variables depended upon the face type. The results from ANOVA confirmed that the changes in each face type group were different.

The results from the present study rejected the null hypothesis that treatment responses are independent of face types. It can be concluded that each face type (short, average, and long faced patients) responds differently to the Begg treatment stage 1. This result is quite similar to the findings of Leighton and Hunter (1982) who found that the spacing and crowding of the mandibular teeth are associated with the face type and that severely crowded patients are likely to have a steep mandibular plane angle and short posterior face height. The findings of the present study and that of Leighton and Hunter (1982) contrast with the findings of Bishara et al. (1994), who could not find any significant difference in post-treatment change in each face type.

The further study of the treatment responses in Begg treatment technique during stage 2, stage 3, and post-treatment in different face types would be interesting and a useful study.

STATEMENT

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University. To the best of my knowledge and belief, it contains no material previously published or written by another person except where due reference has been made in the text of the thesis.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

Kurupin Chaowakitcharoen
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CHAPTER 1 : INTRODUCTION

The rapidly increasing public demand for orthodontic treatment is spread over almost the whole spectrum of age ranges in the community. There exists a large variety of dento-facial patterns throughout the orthodontically treated population of patients.

The introduction of radiographic cephalometrics has enabled orthodontists to classify patients into different dento-facial patterns. Thus, it is of great interest to study the dento-facial changes of patients during and after orthodontic treatment, especially in the case of growing patients.

There exist numerous orthodontic appliances and techniques which produce changes in the dentoalveolar complex and the soft tissues; including Begg, Edgewise, Tweed, and functional, to name just a few available. The Begg treatment technique has been criticized on the basis that an opening of the bite during treatment can only occur through extruding the molars, rather than an intrusion of the upper and lower incisors through the alveolar bone. This extrusion of the molars causes an opening of the mandibular plane angle, and as such has the likelihood of producing a longer face.

CHAPTER 2 : AIMS

The present study aims to describe dento-facial changes which occurred in a selected sample of patients during stage 1 of their orthodontic treatment with the Begg lightwire appliance.

1. To identify a sufficient sample of Class II division 1 patients to enable statistical evaluation of treatment changes.
2. To collect standardized pre-treatment and end of stage 1 records.
3. To utilize cephalometric techniques to analyze soft tissue, skeletal and dental changes for treatment responses.
4. To compare the findings with previous studies using appropriate statistical methods.
5. To test the null hypothesis that treatment responses are independent of face type.

CHAPTER 3 : LITERATURE REVIEW

3.1 GROWTH CHANGES OF THE CRANIO-FACIAL SKELETON AND FACIAL PROFILE

There are large variations of the growth and development between individuals. Different parts of the body grow at different rates and at different times e.g. the formation of the brain case is found to follow the neural growth curve and is completed quite early (Fig. 1 and Fig. 2). The face and dentition are more closely related to the general or somatic growth curve and continue until later in life (Scammon et al., 1930; Scott, 1954).

On average, females reach puberty in the age range from 10.5 to 12 years and during this period, the greatest changes in the face will occur, followed by significant reducing increments for the next two to four years. Males reach puberty about two years later than females, at an average age between 12.5 to 17 years. (Graber, 1969; Baum, 1966; Nanda et al., 1995; Behrents, 1985; Hägg and Taranger, 1982; Bishara et al., 1984; Foley and Mamandras, 1992).

From the many growth studies that have been carried out (Hellman, 1927; Goldstein, 1936; Brodie, 1941; Lande, 1952; Nanda, 1955; Subtelny, 1959; Björk and Skieller, 1983), it can be said that with continuing growth the chin position will usually become positioned more forward and downward in relation to the forehead.

The facial profile relative to the cranial base becomes less convex because the mandible grows more than the maxilla from the age of 12 to 21 years (Björk, 1951; Schudy, 1973). Other studies have found that the mandibular prognathism occurs after seven years and associates with a reduction of the mandibular plane (Lande, 1952; Silverstein, 1954; Downs, 1956; Björk and Skieller, 1974).

3.1.1 Growth of the maxilla

The maxilla grows in a downward and backward rotating direction by the differential resorption of the nasal floor during growth, this being greater anteriorly than posteriorly (Björk and Skieller, 1977). This makes the maxilla profile more concave with growth (Baber and Meredith, 1965).

The rate of maxilla and maxillary dentoalveolar growth increase around puberty. The maxilla grows downward at about 0.7 mm/year relative to the cranial base (Fig. 3) and the maxillary dentoalveolar component grows almost 1 mm/year (Fig. 4). The vertical downward movement of the glenoid fossa is estimated to be about 0.25 to 0.5 mm/year (Fig. 5).

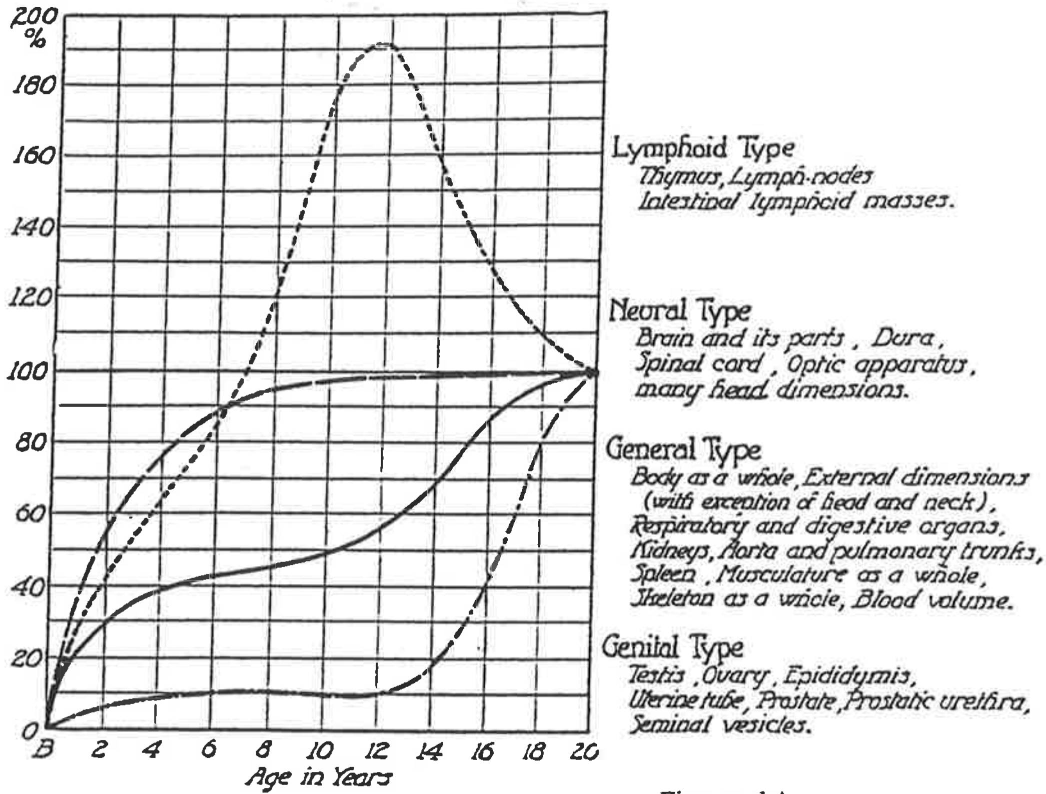


Figure 1A

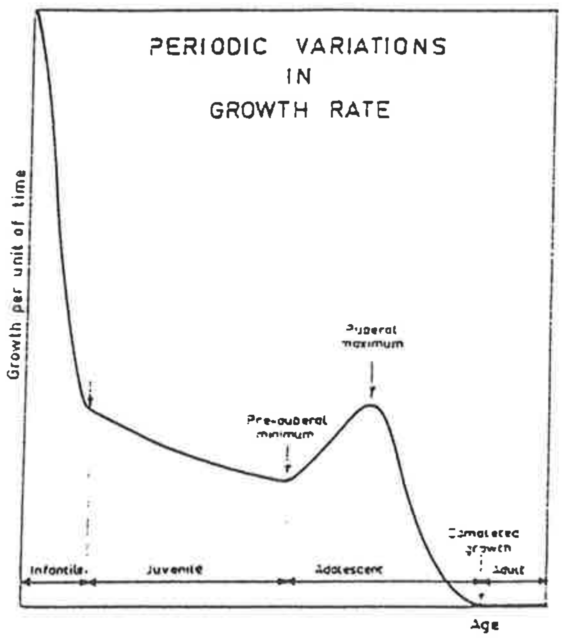


Figure 1B

Fig. 1 Human growth rates

Figure 1A Graph illustrating the time and rate of post-natal growth of the major structures of the body (Scammon curves)

(From Boyd, 1980)

Figure 1B Variation in growth rate in a sample of males

(From Graber, 1969)

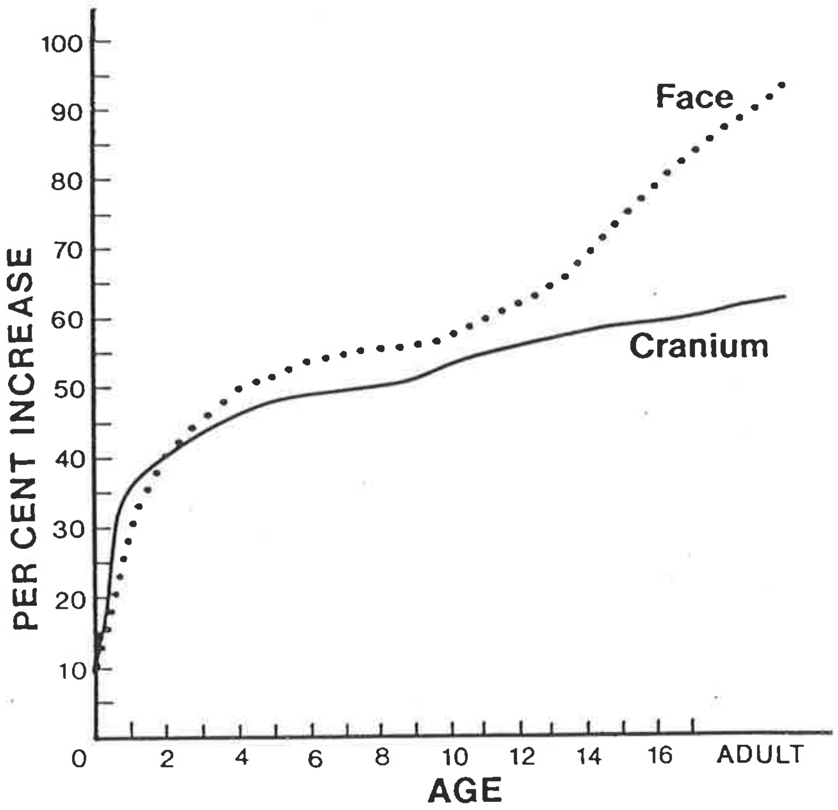


Fig. 2 Comparison of cranial and facial growth (From Scott, 1954)

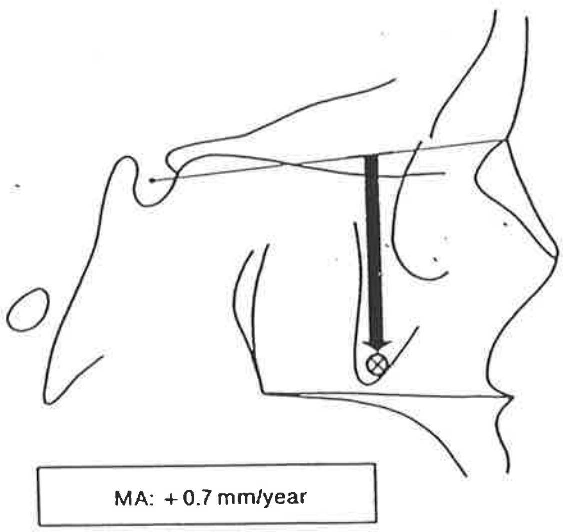


Fig. 3 Average vertical displacement of the basal maxillary structures (MA)

Approximate annual increase in the distance from the anterior cranial base to the implant in the zygomatic process. (From Stöckli and Teucher, 1994)

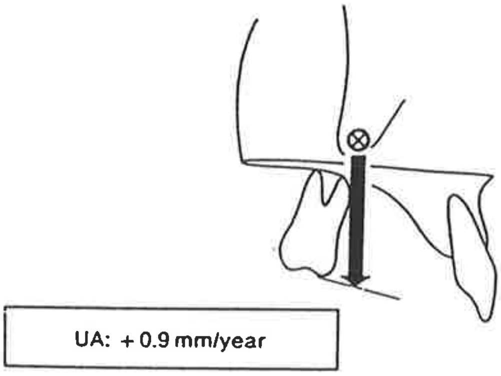


Fig. 4 Average vertical growth of the upper alveolar process (UA)

Approximate annual increase of the distance from the implant in the zygomatic process to the occlusal plane mesial to the first molar.

(From Stöckli and Teucher, 1994)

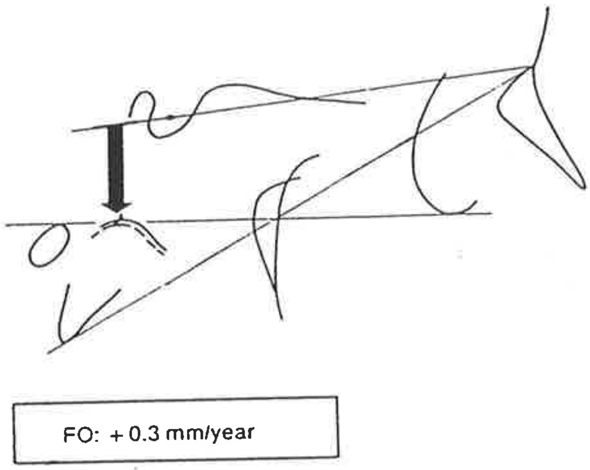


Fig. 5 Average vertical displacement of the glenoid fossae (FO)

(From Stöckli and Teucher, 1994)

Therefore, the vertical development of the maxillary complex measured in the molar region amounts to around 1.5 to 2.0 mm/year (Stöckli and Teucher, 1994, quote the studies of Riolo et al., 1974; Björk and Skieller, 1977; Teucher, 1978; Luder, 1981).

3.1.2 Growth of the mandible

Growth studies using metallic implants have divided mandibular growth into two major patterns, forward and backward rotational growth patterns. In the forward rotational growth pattern displayed by most subjects, the condyles tend to grow vertically and the gonial angle decreases with time. In the backward rotational growth pattern, the condyles tend to grow sagittally and the gonial angle increases (Björk, 1963; Björk, 1969).

The average growth of the mandible, mandibular condyle and mandibular dentoalveolar region also increase around puberty. The mandibular condyle grows about 2.5 mm or more in the pubertal growth spurt period (Fig. 6) and the mandibular dentoalveolus grows about 0.75 mm/year around puberty (Fig. 7). If the growth of maxilla, mandible, maxillary and mandibular dentoalveolar components are combined together, the overall development will be between 2 to 3 mm/year (Stöckli and Teucher, 1994). Individuals do not usually have growth changes corresponding to the average changes, as large variations in the growth occur because of a number of factors. The dominant factors affecting growth are the type of growth pattern and the proximity to the pubertal period. Average growth changes will then need to be adjusted according to these factors for individuals.

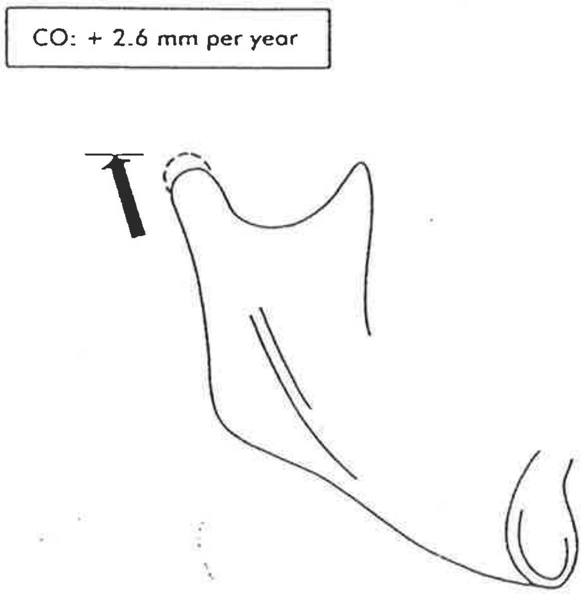


Fig. 6 Average annual growth increment at the mandibular condyles
(From Stöckli and Teucher, 1994)

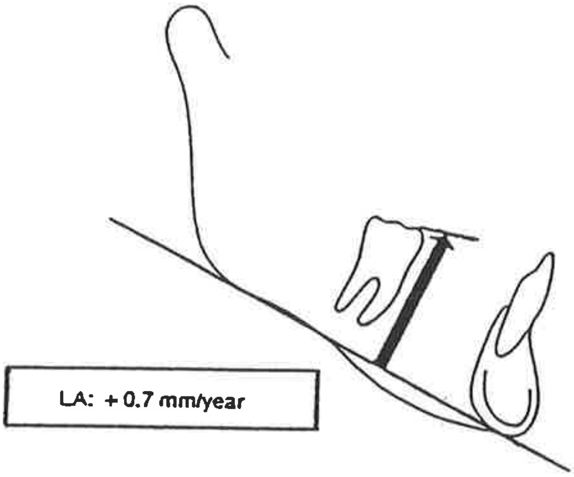


Fig. 7 Average vertical growth of the lower alveolar process (LA)
Approximate annual increase of the distance from the mandibular plane to the mesial cusp of the first molar (From Stöckli and Teucher, 1994)

3.2 GROWTH OF THE SOFT TISSUES

3.2.1 Growth change of the soft tissue profile

The soft tissue profile is closely related to the skeletal and dental structures (Riedel, 1957). The craniofacial skeletal profile becomes straighter with growth, and causes the soft tissue profile to change in the same direction including the chin growing more forward. In contrast, another study has reported that the soft tissue chin and soft tissues of the upper face are not so closely related to the underlying soft tissue (Holdaway, 1983).

3.2.2 Lips

The upper lip increases in length rapidly from one to three years of age and from six to fifteen years. After that the rate of growth slows considerably (Subtelny, 1959; Vig and Cohen, 1979).

The average upper lip length in males is 24 mm from the stomion to subnasale and in females is 20 mm (Burstone, 1967), which is also in agreement with Nanda et al. (1995) who studied the soft tissue profile in adolescents between the ages of 9 to 14 years. They report that males have longer and thicker upper and lower lips than females.

The average increase in the upper lip and lower lip lengths between one to eighteen years is about 6.5 mm and 8.2 mm, respectively, and most pronounced from 9 to 13 years. Vertically, the lower lip grows more than the upper lip (Vig and Cohen, 1979). In general, the upper incisal edge to the upper lip line is the same in males and females (Subtelny, 1959; Nanda et al., 1995).

3.3 ORTHODONTIC TREATMENT

3.3.1 Treatment effects on the facial profile - skeletal

Orthodontic treatment has an affect on the craniofacial growth and development particularly in the growing patients.

The orthodontic treatment in Class II division 1 malocclusion patients retracts a-point and b-point, and caused a change in the anb angle. A reduction of a-point is often reported to be more significant than that of b-point (Silverstein, 1954; Stoner et al., 1956; Taylor, 1969; Barton, 1973; Williams, 1977; Cohen, 1983).

Orthodontic treatment also changes the occlusal plane and mandibular plane direction, normally due to molar elevation (Silverstein, 1954; Wylie, 1955; Stoner et al., 1956; Ricketts, 1960; Williams, 1968; Barton, 1973; Cross, 1977; Stöckli and Teucher, 1994) and causes the mandible to grow more vertically in the treated patients (Mair and Hunter, 1992). Normally then, the mandibular plane and occlusal plane tend to return to their original orientation post-treatment (Williams, 1968; Fotis et al., 1985). Therefore, during the treatment of a moderate to high angle Class II malocclusion, it is important to control the vertical dimension (Björk, 1969; Isaacson et al., 1977; Pearson, 1986; Nielsen, 1991). If the vertical control is lost, the mandible can rotate downward and backward, decreasing the potential for a favourable mandibular change particularly in steep mandibular plane angles or long face patients.

Cephalometric analysis has been used as the criterion for assessing vertical dimension control and to observe whether the treatment is successful (Gebeck, 1989; Merrifield, 1989; Horn, 1992). Successful treatment is indicated by an increase of the posterior face height and unsuccessful treatment is shown by no increase in posterior face height, but the anterior face height increases (Gebeck, 1989; Merrifield, 1989; Horn, 1992; Sinclair et al., 1994).

Nonextraction treatment emphasizes the downward and backward rotation of the mandible (Schudy, 1964; Chua et al., 1993) while extraction treatment relates to the upward and forward rotation of the mandible (Schudy, 1964), but another study does not find any association with extraction treatment with the upward and forward rotation of the mandible (Chua et al., 1993).

The different face types (short, average, and long faces) in Class II division 1 patients do not show the same response with treatment. The distance from the upper maxillary incisor edge to the reference line from a-point to pogonion increases in long-faced, and decreases in short-faced patients post-treatment. Long face females show the greatest increase of the anterior face height and the largest decrease in the maxillary arch length compared to the other face types in post-treatment (Bishara et al., 1994).

3.3.2 Treatment effects on the facial profile - soft tissue

There are different reports relating to the treatment effect on the soft tissue profile particularly the amount of upper lip retraction following the upper incisor retraction.

The retraction of the upper incisors causes the upper lip to move backwards (King, 1960; Bloom, 1961; Rudee, 1964; Wisth, 1974; Lo and Hunter, 1982; Talass et al., 1987).

Many reports have reported the ratio of the upper incisor retraction per backward movement of upper lip e.g. 1.0:0.5 mm by King (1960), 3.0:1.0 mm by Ricketts (1960), 2.9:1.0 mm for the upper lip and 1.1:1.0 mm in the lower lip by Rudee (1964). The retraction of the upper and lower lips is greater in the large overjet group than in the small overjet group (Wisth, 1974). In contrast, some studies conclude that lip prominence reduction is not necessarily related to the tooth movement but depends upon other factors e.g. muscle size and tonicity (Salzmann, 1964).

Some studies report that the effect of orthodontic treatment on the upper and lower lips can be predicted from the degree of mandibular rotation because of the close relationship between overlying soft tissue and the craniofacial skeleton (Rains and Nanda, 1982), whereas other studies can not find any correlation in predicting soft tissue response from incisor retraction.

The retraction of the upper incisors has been reported to reduce the vermilion height in the upper lip by 1.6 mm and in the lower lip by 1.3 mm during orthodontic treatment (Jacobs, 1978; Perkins and Staley, 1993), whereas another similar study found no change in lip vermilion (Abdel Kader, 1983).

The nasolabial angle is one of the important soft tissue variables which is reduced by growth (Riolo et al., 1974; Bhatia and Leighton, 1993), but is opened by orthodontic treatment in both extraction and nonextraction patients (Lo and Hunter, 1982; Finnöy et al., 1987; Talass et al., 1987).

It is believed that the extraction of the premolars for the purpose of orthodontic treatment caused a 'dished-in profile', but many studies have proved that this statement is not true (Farrer, 1984; Drobocky and Smith, 1989; Luppanapornlarp and Johnston, 1993) and one study has shown that the premolar-extracted patients have significantly more protrusion of the soft tissue lip area than the nonextracted patients (Luppanapornlarp and Johnston, 1993).

However, almost all of the studies of soft tissues e.g. lip position, nasolabial angle, and labiomental angle show large measurement errors.

3.3.3 Begg treatment effects

The Begg appliance is very effective in moving teeth in the alveolar bone (Riedel, 1960).

The Begg treatment technique is generally divided into 3 stages.

1. Stage 1: This stage is conducive to the rapid movement of anterior teeth under the light forces generated by the arch wires and intermaxillary elastics. The objectives of this stage are :
    a. open or close the anterior bite;
    b. align the teeth;
    c. achieve Class I or overcorrected Class I molar relationship.
2. Stage 2 : this stage is mainly the closing of residual posterior extraction spaces.
3. Stage 3 : this stage of treatment is involved with correcting or overcorrecting the axial inclination and angulation of teeth.

The Begg technique has been criticized for making the mandible rotate downward and backward, extruding the lower molars, tipping the occlusal plane, opening the y-axis angle and causing an elongation of the face (Riedel, 1960).

The occlusal plane and mandibular plane tend to flatten with growth. The Begg treatment effect increases the steepness of both planes (O'Reilly, 1979; Williams, 1968; Haw-cited by Parker, 1969; Farrer, 1984) because of the intrusion of the lower incisor and the extrusion of the lower molars (Fig. 8, 9, 10, 11).

The upper incisors usually are slightly elongated (Williams, 1968). The lower incisors are proclined from Begg treatment (Bijlstra, 1969; Edler, 1977; Williams, 1977). This is opposite to the finding of Sim and Springate (1995) who report that the lower incisors are retroclined.

The upper molars move distally because of the treatment mechanics from the anchorage bend and Class II elastics (Cadman, 1975) but another study found no change of the upper molars in the anteroposterior position (Meistrell et al., 1986).

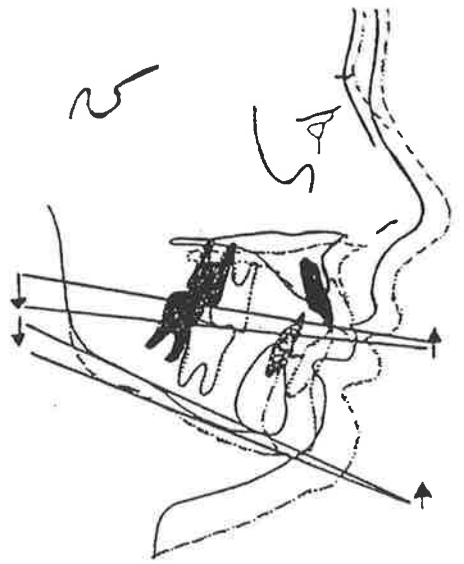


Fig. 8 Example of a patient with a relatively flat mandibular plane which becomes even flatter during a period of free growth between 7 to 12 years of age. FMA went from 26° to 23°. The occlusal plane tends to flatten also.

(From Williams, 1968)

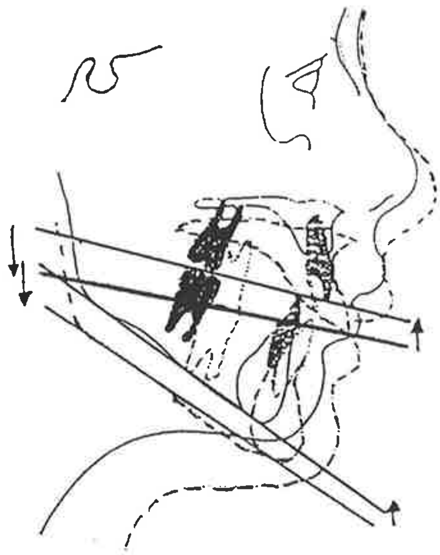


Fig. 9 Example of a patient with a relatively steep mandibular plane which flattens very little during a period of free growth between 7 to 12 years of age. FMA went from 36° to 35°. Mild flattening of occlusal plane does occur.

(From Williams, 1968)

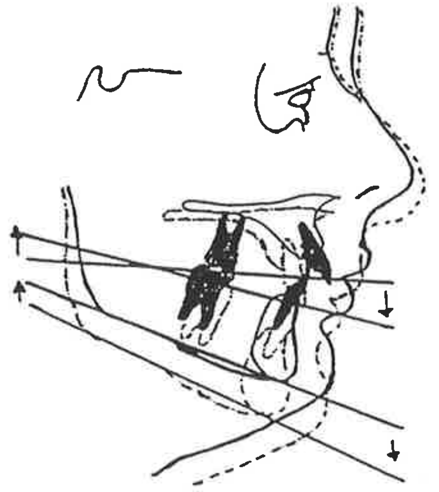


Fig. 10 The flattening process of the mandibular plane has been counteracted by treatment effects. Occlusal plane flattening has also been countermanded.
(From Williams, 1968)

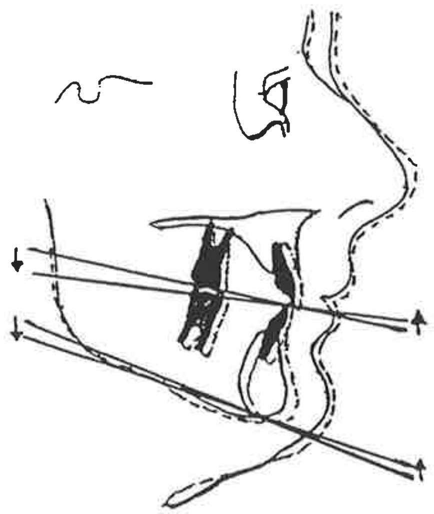


Fig. 11 Following treatment, the dominance of the flattening trend of the occlusal and mandibular planes reasserted itself and any temporary inhibiting effects of treatment were more than compensated for. Occlusal plane reverted toward its original cant.
(From Williams, 1968)

There is mesial movement of the lower molars (Meistrell et al., 1986; Cadman, 1975) though it has been reported that a mesio-occlusal movement of the lower molars also occurs (Cadman, 1975).

The Begg treatment also reduces the anb angle by causing the restriction of maxillary growth or posterior movement of the a-point (Haw-cited by Parker, 1969; Pridimore, 1969).

During the retention period, both the mandibular plane and Downs occlusal plane angle decrease (O'Reilly, 1979; Williams, 1968; Haw-cited by Parker, 1969).

The study of skeletal changes from pre-treatment to stage 2 and pre-treatment until the final stage of Begg technique in 25 patients with anterior deep bite shows that there are vertical height increases of the upper molars relative to the maxillary plane, and the lower molar relative to the mandibular plane, and a vertical height decrease of the upper and lower incisors (Table 1). The Frankfort mandibular plane angle increases from the beginning of treatment till the end of stage 2 from 0.5 to 4 degrees (Rocke, 1964). In contrast, some studies report no change of steepness of the mandibular and occlusal planes (Lew, 1989; Meistrell et al., 1986).

Table 1 Changes in vertical dimension of molars and incisors (From Rocke, 1964)

vertical height changes	start of treatment to the end of stage 2	start of treatment to finish
lower molar (mm)	+3.1 mm	+3.6 mm
upper molar (mm)	+0.7 mm	+1.2 mm
lower incisor (mm)	-3.0 mm	-2.0 mm
upper incisor (mm)	-1.1 mm	-0.2 mm

The study comparing the results of Begg technique and Edgewise technique with cervical pull head gear reports that the sample in Edgewise technique shows more extrusion of the upper molars than that of the Begg technique. The mandibular molars are extruded a similar amount, but surprisingly mandibular plane relative to maxillary plane is opened more with the Begg technique (Barton, 1973).

There is a study comparing the vertical skeletal changes from 49 nonextraction patients treated by functional appliances (Andresen and Harvold) and 30 extraction patients treated by the Begg appliance. In both groups, the mandible rotates downward and backward and the ratio of anterior to posterior face height is constant (Ball and Hunt, 1991).

Another study compares the soft tissue profile between the 30 nonextraction patients treated by Activator with 30 extraction patients treated by the Begg appliance. The upper incisors are retracted more in the Begg treated group than in the Andresen treated group, but the final upper lip position is slightly different (Looi and Mills, 1986).

The study of 32 bimaxillary protrusion patients of Chinese background treated by extraction of four first premolars using Begg technique, reports that there is an upper and lower lip retraction (Lew, 1989).

Summary

The Begg treatment technique is effective in correcting malocclusions. The correction of Class II division 1 malocclusions by Begg treatment technique occurs from the combinations of :

1. restriction of maxillary growth;
2. distal movement of maxillary molars;
3. mesial movement of the lower molars.

Some studies have reported that the corrections come from other factors as well e.g. proclination of the lower incisors, and intrusion of the upper and lower incisors.

CHAPTER 4 : MATERIALS AND METHODS

4.1 SAMPLE SELECTION

The sample for the present study consisted of the orthodontic records of 85 patients treated with full-banded Begg light-wire appliances (described by Begg and Kesling, 1977) in the Post Graduate Master's degree programme in Orthodontics at the University of Adelaide. The records collected included the hospital case notes, post-graduate treatment folders (written by the operator), study models and cephalometric radiographs obtained pre-treatment and at stage 1 orthodontic treatment.

All patients had been diagnosed as displaying an Angle Class II, division I pattern of malocclusion. In all cases there were Class II molar relationships and increased overjet.

The cases were selected on the basis of the following criteria :

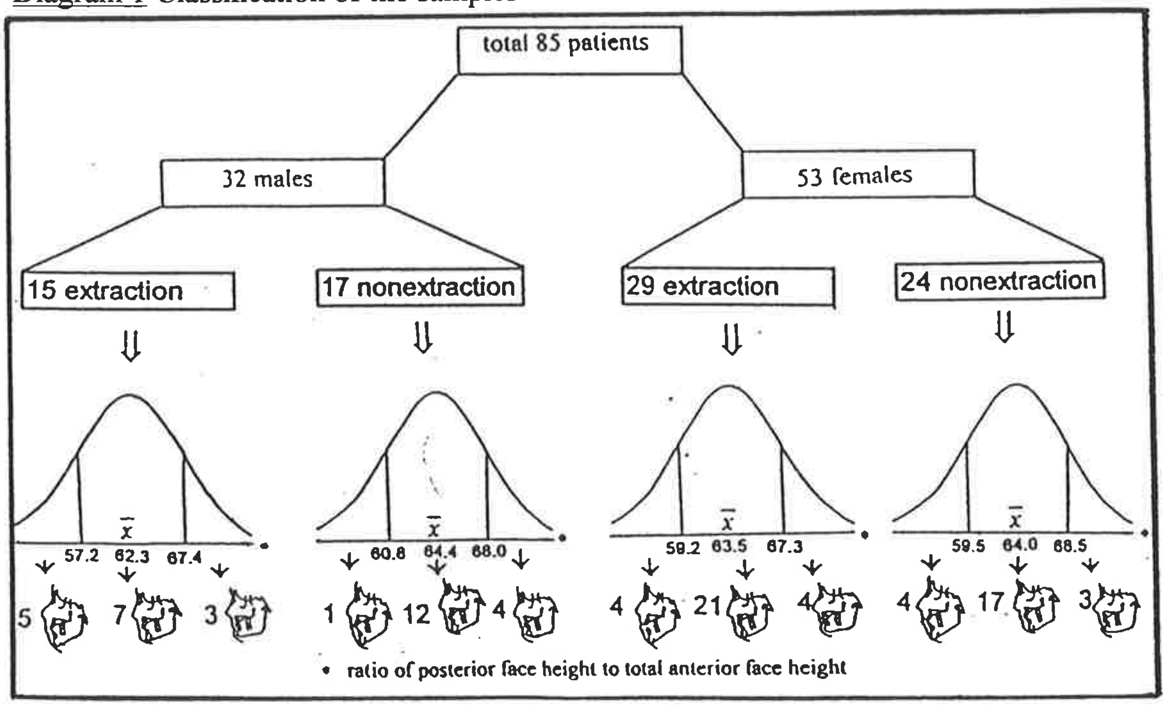
1. Complete records. Primarily the presence of pre-treatment and stage 1 treatment cephalograms;

2. Class II, division I pattern of malocclusion, Class II molar relationship (all cases had some degree of increased overjet > 4 mm);

3. The ages of the patients involved in the present study were in the range from 10.5 to 16 years at the beginning of the treatment.

All of the patients in the present study, which included 32 males and 53 females, were allotted into one of four groups according to gender and the type of treatment performed. The number of subjects in each group were: 15 male-extraction; 17 male-nonextraction; 29 female-extraction; and 24 female-nonextraction. Each group was then subdivided according to face type, using the ratio of posterior face height to total anterior face height, into high, average, and low ratio groups (Diagram 1).

Diagram 1 Classification of the samples



4.2 RADIOGRAPHY

All radiographs were obtained in the Radiology Department of the Adelaide Dental Hospital using Lumex cephalometric head device and Philips x-ray tube.

The cephalostat was of standard design (Lumex, Copenhagen) comprising a film holder, head-holder with plastic ear-rods, aluminium wedge for soft tissue imaging and light beam for head positioning.

The distance from the source to the mid-sagittal plane and from the mid-sagittal to the film plane was constant. Therefore, the enlargement factor at the mid-sagittal plane was constant at 8.8 % (Fig. 12).

Kodak brand films were used and exposures were standardized and varied according to the film specifications.

Intensifying screens were used in order to reduce dosage and a grid was used to reduce the effect of radiation scatter.

The radiographic procedure has been standardized as much as is possible, however, the Radiology Department has a large staff turnover.

The steps taken to standardize procedure were:

1. film loaded in holder;
2. patients positioned in a standing position, looking straight ahead. Ear-rods placed in external auditory meatus, head holder adjusted upwards such that the rods exerted pressure against the superior margins of the cartilaginous meatus causing the patient to obtain a true lateral position;
3. Aluminium wedge positioned, profile completeness checked using light beam;
4. mid-sagittal plane of the face checked in relation to the mid-sagittal plane of the head holder by using the vertical light beam;
5. vertical head inclination adjusted to the Frankfort horizontal using horizontal light beam (at infraorbital region);
6. instructed to close teeth into centric occlusion;
7. the lip position was not standardized (the patient may have been instructed to relax their lips).
8. exposure made.

The film processing was standardized according to the film type by using an automatic processor for all films.

4.3 PILOT STUDY

In order to learn the techniques involved and to eliminate any problems in the procedures (e.g. tracing and superimposition, digitizing, plotting and transmission of data), cephalograms of 10 patients of pre-treatment and at stage 1 (20 tracings) were assessed.

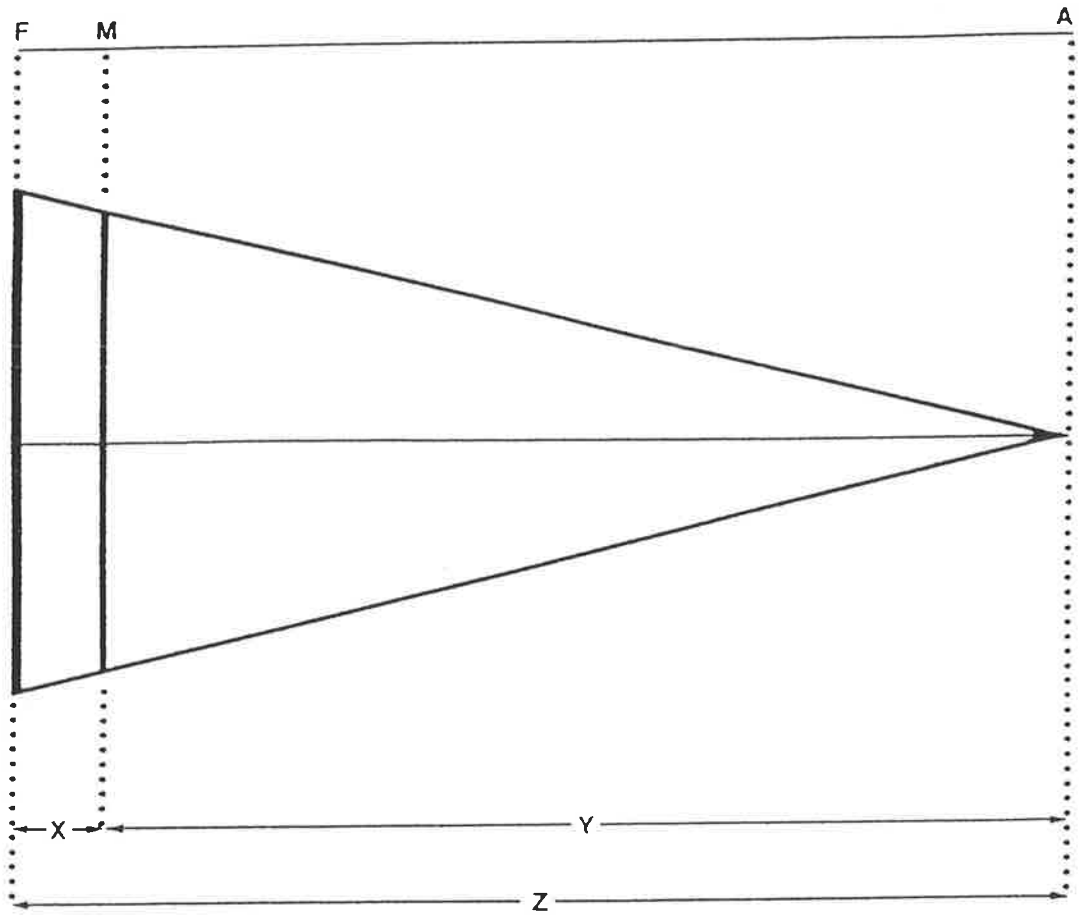


Fig. 12 Calculation of the enlargement factor for points lying on the mid-sagittal plane (x, y, z drawn to scale)

F = Film Plane
M = Mid-sagittal Plane
A = Focus
X = 160 mm
Y = 1818 mm
Z =1978 mm

E = Enlargement Factor

$$E = \left(\frac{Z}{Y} - 1\right) * 100 = \left(\frac{1978}{1818} - 1\right) * 100 = 8.8\ \%$$

4.4 TRACING AND SUPERIMPOSITION

All radiographs were traced under standardized conditions which included a darkened room and a viewing screen with a light of variable intensity and curtains to reduce screen size. In addition, pieces of cardboard were used to further restrict illumination to the area of interest to facilitate landmark identification.

The landmarks (Fig. 13) were traced. The symbols and the variable abbreviation are in Table 2 and Table 3. The interlabial gap is the difference between the average value of variable 45 (sll-y) and variable 43 (iul-y). The definition of each landmark is in Appendix 1. Tracings were made with a 0.5 mm "H" clutch pencil on transparent drafting paper. The two films for each subject were viewed together. The radiographs were superimposed using the standard procedure of Björk and Skieller (1983).

Superimposition allowed the transfer of the reference planes of the first (pre-treatment) film to the second (at stage 1 treatment) film based on the stable structures of the anterior cranial base.

The structures upon which the superimpositions were based were as follows (Fig. 14) :

1. anterior wall of sella turcica;
2. planum sphenoidale;
3. anterior contours of the middle cranial fossa;
4. contour of the cribriform plate;
5. inner surface of the frontal bone;
6. bony trabeculations, especially of the ethmoid bone.

(Björk and Skieller, 1983).

This method of superimposition allowed facial growth and treatment changes to be studied in relation to the cranial base. The reference planes selected were sella-nasion 7° (of the first radiograph, transferred via superimposition to the second radiograph) which formed the x-axis, and a perpendicular to sella-nasion 7° through sella (first radiograph transferred to second radiograph) which formed the y-axis of the cartesian coordinate system with sella at the origin. After tracing the first radiograph and superimposing to transfer the reference system to the second radiograph the landmarks of the second film were traced.

In addition to the 170 tracings (85 subjects) made for the major study, the radiographs of 10 patients (20 tracings) selected at random were retraced and superimposed in order to study the error of the method (Chapter 4.10).

4.5 DIGITIZING

The tracings were digitized on a Hewlett Packard 9874A digitizer using a Hewlett Packard 9815A controller, the data being stored on Hewlett Packard data tapes. Programme number E6 on the positive track of the data tapes (author, Prof. T. Brown) was used for digitizing. Digitizing allowed the coordinates of all landmarks in relation to the x and y axes to be recorded on the negative track of the data tapes in sequential files.

Fig. 13 Landmarks and order of digitizing

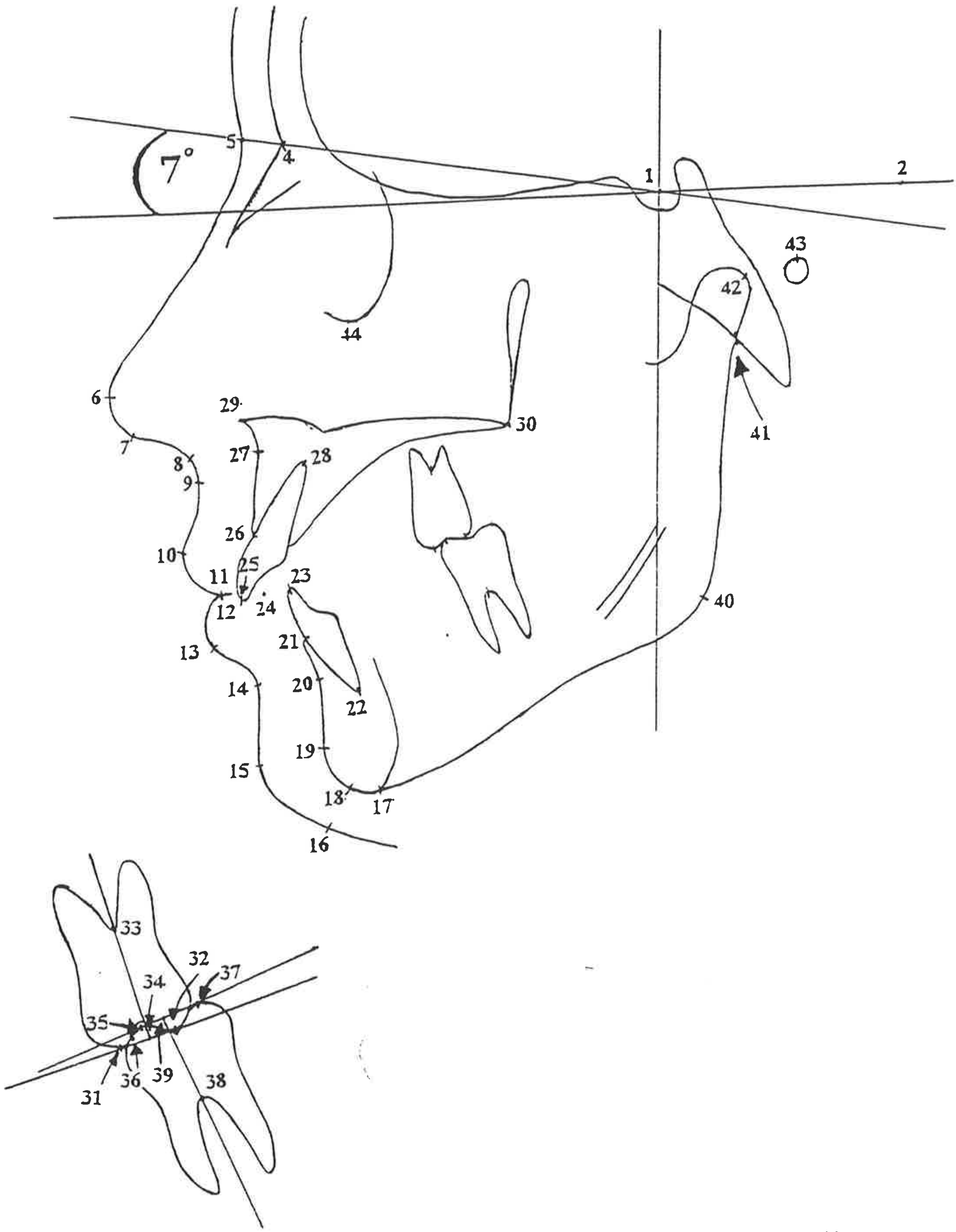


Table 2 Landmarks and symbols for digitizing (landmark definitions in chapter 8.1)

number	abbreviation	name of landmarks
1	s	sella
2	x	x-axis
3	n-origin	nasion origin
4	n-stage 1	nasion at stage 1
5	nas	soft tissue nasion
6	prn	pronasale
7	cm	columella point
8	sn	subnasale
9	sls	superior labial sulcus
10	ls	labrale superius
11	iul	inferior aspect upper lip
12	sll	superior aspect lower lip
13	li	labrale inferius
14	ils	inferior labial sulcus
15	pos	soft tissue pogonion
16	gns	soft tissue gnathion
17	me	menton
18	gn	gnathion
19	pog	pogonion
20	b	b-point
21	id	infradentale
22	lia	lower incisor apex
23	iei	incisal edge inferior
24	ies	incisor edge superior
25	adp	anterior Downs point
26	sd	supradentale
27	a	a-point
28	uia	upper incisor apex
29	ans	anterior nasal spine
30	pns	posterior nasal spine
31	umt	upper molar mesial cusp tip
32	udt	upper molar distal cusp tip
33	ufur	upper molar furcation
34	umf	upper molar perpendicular to occlusal plane surface of molar
35	lmt	lower molar mesial cusp tip
36	pdp	posterior Downs point
37	ldt	lower molar distal cusp tip
38	lfur	lower molar furcation
39	lmf	lower molar furcation perpendicular to occlusal surface of molar
40	go	gonion
41	ar	articulare
42	co	condylion
43	po	porion
44	or	orbitale

Table 3 Variable abbreviation

number	abbreviation	name of variables
1	sna	sna angle
2	snb	snb angle
3	sn7/dop	sn7 to Downs occlusal plane angle
4	mxp/dop	maxillary plane to Downs occlusal plane angle
5	mdp/dop	mandibular plane to Downs occlusal plane angle
6	mxp/sn	maxillary plane to sn plane angle
7	mdp/sn	mandibular plane to sn plane angle
8	mxp/mdp	maxillary plane to mandibular plane angle
9	u1/sn7	upper incisor to sn7 plane angle
10	u1/mxp	upper incisor to maxillary plane angle
11	l1/sn7	lower incisor to sn7 plane angle
12	l1/mdp	lower incisor to mandibular plane angle
13	ar/go/gn	gonial angle
14	ii	interincisal angle
15	u6/sn7	upper first molar to sn7 plane angle
16	u6/mxp	upper first molar to maxillary plane angle
17	l6/sn7	lower first molar to sn7 plane angle
18	l6/mdp	lower first molar to mandibular plane angle
19	ar-gn	distance from articulare point to gnathion point
20	co-gn	distance from condylion point to gnathion point
21	co-a	distance from condylion point to a-point
22	uafh	upper anterior face height
23	lafh	lower anterior face height
24	tafh	total anterior face height
25	pfh	posterior face height
26	lafh/tafh	ratio of lower anterior face height to total anterior face height
27	pfh/tafh	ratio of posterior face height to total anterior face height
28	u1-mxp	distance from upper incisor to maxillary plane
29	l1-mdp	distance from lower incisor to mandibular plane
30	u6-mxp	distance from upper first molar to maxillary plane
31	l6-mdp	distance from lower first molar to mandibular plane
32	prn-gns	distance from pronasale to soft tissue gnathion
33	nasolab/a	nasolabial angle
34	labiomen/a	labiomental angle
35	oj	overjet
36	ob	overbite
37	ao/bo	Wits (ao/bo)
38	bx	distance of b-point along the x-axis
39	by	distance of b-point along the y-axis
40	pog-x	distance of pogonion along the x-axis
41	pog-y	distance of pogonion along the y-axis
42	iul-x	distance of inferior aspect upper lip along x-axis
43	iul-y	distance of inferior aspect upper lip along y-axis
44	sll-x	distance of superior aspect lower lip along x-axis
45	sll-y	distance of superior aspect lower lip along y-axis

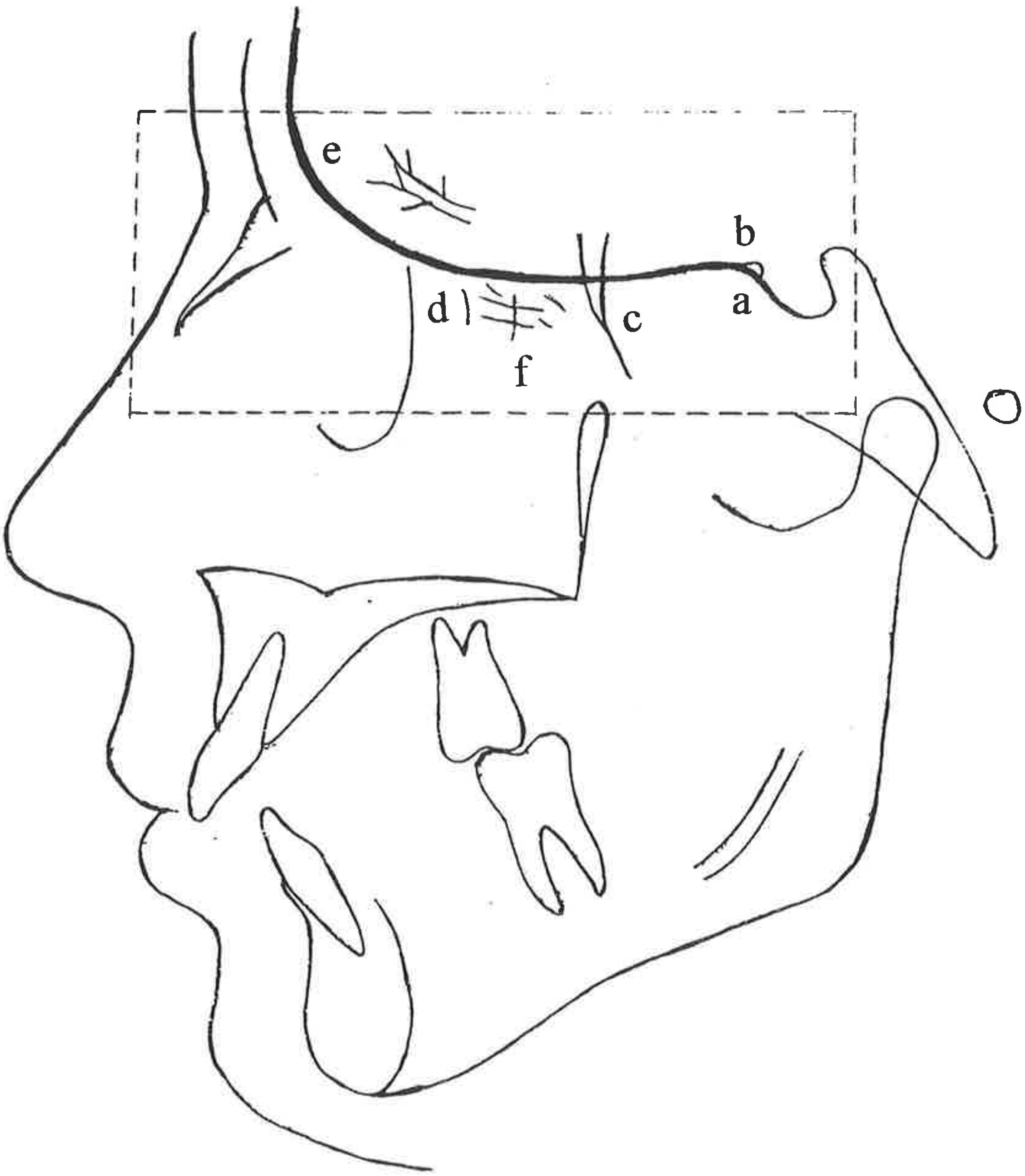


Fig. 14 Principal Structures used for Cranial Base Superimposition

a. anterior wall of sella turcica
b. planum sphenoidale
c. anterior contours of the middle cranial fossa
d. contour of the cribiform plate
e. inner surface of the frontal bone
f. bony trabeculations, ethmoid bone

(Derived from Björk and Skieller, 1983)

The procedure used for digitizing was as follows :

1. digitizer screen cleaned using ethyl alcohol;
2. data tape initialized and files constructed; one file per subject (tracing);
3. digitizing programme loaded into controller;
4. tracing mounted on screen using tape;
5. programme run :
    a. subject's identity number and file number recorded;
    b. axis alignment using two points on the sella-nasion line (sella and x-align);
    c. landmarks were digitized in a specific order (Table 2) by aligning the cursor over the landmark and pressing the button on the cursor to record the coordinates of the landmark;
    d. the controller recorded the information on the data tape and the run stopped;
6. the procedure was repeated for a new tracing (steps 1 through 5).

Three data tapes were required (including one for the error study).

4.6 PLOTTING

Identification information and coordinate data stored on the negative track of the data tapes were plotted on A3 size paper using a Hewlett Packard 9872A plotter and the 9815A controller. Programme number E4 on the positive track of the data tape (author, Prof. T. Brown) was used.

Plots were made for all tracings. The tracings were then superimposed upon the plots in order to visually check the accuracy of digitizing. This ensured that the information such as the subject's identity number, age and landmarks were recorded correctly. Plots containing "wild" landmarks were later redigitized on the same file and re-plotted until all plots accurately corresponded to their respective tracings.

4.7 TRANSMISSION OF DATA

The coordinates of the landmarks and identification information were transferred from the magnetic disc storage to the University's central SUN system via ethernet connections for further processing.

4.8 COMPUTATION OF VARIABLES

The programme XY data (author, Prof. T. Brown) was used to calculate the variables. The input data in the form of x and y coordinates of all points was computed using this programme with trigonometric functions. The enlargement factor of 8.8% at the mid-sagittal plane was used in computation of the linear variables to produce a result in millimeters. The programme allowed for the angular variables to be displayed in the appropriate way (for example, an acute angle could be described in terms of the value n or 180°-n). The print out was checked for accuracy by hand measuring from the plots and/or tracings superimposed on each print out. All angular variables were checked to ensure that they had been calculated in the appropriate way.

4.9 STATISTICAL EVALUATION

The statistical analysis used is outlined :

1. Basic descriptive statistics including means, standard deviations, variances, ranges and other suitable basic statistics were calculated for the pre-treatment data and at the end of stage 1 for each variable for males, females and the total sample.

2. Detailed analysis.

2.1 Unpaired t-tests were used to compare the differences between groups e.g. male versus female, male-extraction versus male-nonextraction, female-extraction versus female-nonextraction, etc.

2.2 Correlation analysis was applied to assess the relationship between the change in each variable with treatment and the face type (ratio of posterior face height to total anterior face height).

2.3 Analysis of variance (ANOVA) was also applied to compare mean changes in each variable among the three face type groups (high ratio, average ratio, and low ratio of posterior face height to total anterior face height).

4.10 ERROR STUDY

A group of ten patients (twenty tracings) was selected at random from the total sample to assess the error of tracing and superimposition between the first and second determinations. Basic descriptive statistics were calculated for each group.

The following terms and symbols are used in the text and tables :

mean	arithmetic mean of a series of measurements
sd	sample standard deviation
SE	standard error of the measurement
t	value of "t" computed from Student 's "t-test"
mean diff	mean difference of the two determinations
E(m) diff	standard error of the mean difference
Se	standard deviation of a single determination
E(var)	percentage error variance
n	sample size

Calculations relating to the error study were as follows :

$$\text{mean diff} = \frac{\sum diff}{n}$$

E(m) diff = $\frac{sd\ diff}{\sqrt{n}}$

t (Student 's paired t-test) = $\frac{mean\ diff}{E(m)\ diff}$

Se = $\sqrt{\frac{\sum diff^2}{2n}}$ (Dahlberg, 1940)

E(var) = $\frac{Se^2}{sd^2} * 100$

Where diff = difference in readings between first and second determinations.

n = number of double determinations.

CHAPTER 5 : RESULTS

5.1 ERROR DETERMINATION

The error study comprised random sampling of 20 radiographs (ten pre-treatment, and ten at stage 1) from ten patients to assess errors in tracing the radiographs and errors in digitizing.

The errors from digitizing and data transmission were negligible. In the present study, every tracing was double-checked for the accuracy of digitizing by superimposing the tracing on the plotting paper again before saving the data to the diskette.

The results of the double determinations (Table 4) showed that :

1. t-values for most of the variables were less than 2.093, the critical t-value at the 5% level of probability, except variable mdp/sn (t = 2.15), pfh (t = 2.51), lafh/tafh (t = 2.37). None of the variables had a t-value more than 2.861, the critical t-value at the 1% level of probability. This indicated that there was little evidence of systematic errors.

2. The Dahlberg value (Se) was large for the following variables :
variable 23. upper first molar to sn7 plane angle (u6/sn7) = 4.16°;
variable 24. upper first molar to maxillary plane (u6/mxp) = 4.25°;
variable 25. lower first molar to sn7 plane (l6/sn7) = 2.90°;
variable 26. lower first molar to mandibular plane angle (l6/mdp) = 3.06°;
variable 41. nasolabial angle (nasolab/a) = 4.33°;
variable 42. labiomental angle (labiomen/a) = 3.62°.

This indicated that those variables describing upper and lower first molar angulations, and nasolabial angle, had relatively high standard deviations of a single determination.

3. the ratios of the error variance to total observed variance were relatively high for upper and lower molar position/angulation, and nasolabial angle. This indicated that these variables were less reliable than other variables.

3.1 variables that showed mildly high percentage error variance (10<E(var)< 20) were mxp/uop, mxp/dop, mdp/lop, co-gn, and u6-mxp.

3.2 variable that showed a moderately high percentage error variance (20<E(var)<30) was the nasolabial angle. This means that this variable has an even lower reliability than those in 3.1.

3.3 variables involved with the upper and lower molar angulations, u6/sn7, u6/mxp, l6/sn7, l6/mdp, showed a high percentage error variance (E(var) >30). These variables may be unreliable and were not used for interpretation in the results of the present study.

Table 4 Results of double determinations

no.	variable	mean diff	t-value	Se	Se^2	sd	sd^2	E(var)
1	sna	0.19	0.80	0.73	0.53	3.90	15.21	3.50
2	snb	0.21	1.48	0.46	0.21	3.50	12.25	1.73
3	sn7/uop	0.17	0.37	1.40	1.96	4.80	23.04	8.51
4	sn7/lop	0.43	0.87	1.54	2.37	6.50	42.25	5.61
5	sn7/dop	0.83	1.84	1.51	2.28	4.90	24.01	9.50
6	mxp/uop	0.16	0.35	1.42	2.02	4.40	19.36	+ **10.42**
7	mxp/lop	0.7	1.26	1.78	3.17	5.90	34.81	9.10
8	mxp/dop	0.9	1.73	1.73	2.99	4.50	20.25	+ **14.78**
9	mdp/uop	-0.26	-0.63	1.26	1.59	4.40	19.36	8.20
10	mdp/lop	-0.77	-1.57	1.60	2.56	4.40	19.36	+ **13.22**
11	mdp/dop	-0.7	-1.93	1.17	1.37	3.70	13.69	10.00
12	mxp/sn	-0.54	-2.02	0.90	0.81	3.00	9.00	9.00
13	mxp/sn7	-0.27	-1.10	0.78	0.61	2.90	8.41	7.23
14	mdp/sn	-0.54	* **-2.15**	0.86	0.74	5.30	28.09	2.63
15	mdp/sn7	-0.34	-1.48	0.74	0.55	5.10	26.01	2.11
16	mxp/mdp	-0.07	-0.22	0.96	0.92	5.00	25.00	3.69
17	u1/sn7	-0.28	-0.56	1.54	2.37	8.10	65.61	3.61
18	u1/mxp	-0.53	-1.10	1.53	2.34	7.70	59.29	3.95
19	l1/sn7	0.54	1.09	1.56	2.43	7.10	50.41	4.83
20	l1/mdp	-0.2	-0.37	1.69	2.86	6.90	47.61	6.00
21	ar/go/gn	-0.21	-0.64	1.03	1.06	5.13	26.32	4.03
22	ii	0.82	1.24	2.12	4.49	9.70	94.09	4.78
23	u6/sn7	1.53	1.17	4.16	17.31	4.60	21.16	+ + + **81.78**
24	u6/mxp	1.26	0.93	4.25	18.06	4.60	21.16	+ + + **85.36**
25	l6/sn7	-0.94	-1.02	2.90	8.41	5.20	27.04	+ + + **31.10**
26	l6/mdp	1.28	1.35	3.06	9.36	5.50	30.25	+ + + **30.95**
27	ar-gn	0.07	0.25	0.86	0.74	4.80	23.04	3.21
28	co-gn	0.83	1.65	1.66	2.76	5.14	26.42	+ **10.43**
29	co-a	0.41	0.96	1.36	1.85	4.53	20.52	9.01
30	uafh	-0.24	-1.23	0.63	0.40	3.14	9.86	4.03
31	lafh	0.23	1.38	0.54	0.29	4.72	22.28	1.31
32	tafh	-0.16	-1.19	0.42	0.18	6.27	39.31	0.45
33	pfh	0.49	* **2.51**	0.69	0.48	4.97	24.70	1.93
34	lafh/tafh	0.32	* **2.37**	0.48	0.23	2.24	5.02	4.59
35	pfh/afh	0.4	1.88	0.72	0.52	4.34	18.84	2.75

no.	variable	mean diff	t-value	Se	Se^2	SD	SD^2	E(var)
36	u1-mxp	0.13	0.75	0.53	0.28	2.57	6.60	4.25
37	l1-mdp	-0.26	-1.60	0.52	0.27	2.64	6.97	3.88
38	u6-mxp	0.11	0.41	0.78	0.61	2.01	4.04	**+ 15.06**
39	l6-mdp	0.04	0.17	0.66	0.44	2.55	6.50	6.70
40	prn-gns	-0.21	-0.75	0.86	0.74	5.61	31.47	2.35
41	nasolab/a	-0.54	-0.38	4.33	18.75	9.40	88.36	**+ + 21.22**
42	labmen/a	-1.6	-1.43	3.62	13.10	17.95	322.20	4.07
43	oj	-0.05	-1.11	0.14	0.02	2.33	5.43	0.36
44	ob	0.07	1.84	0.13	0.02	2.08	4.33	0.39
45	ao/bo	0	0.00	0.20	0.04	2.13	4.54	0.88
46	bx	0.02	0.12	0.38	0.14	5.70	32.49	0.44
47	by	-0.01	-0.17	0.18	0.03	5.13	26.32	0.12
48	pogx	-0.14	-1.67	0.31	0.10	6.42	41.22	0.23
49	pogy	0.06	0.44	0.39	0.15	5.60	31.36	0.49
50	iulx	-0.18	-1.58	0.37	0.14	5.26	27.67	0.49
51	iuly	-0.03	-0.77	0.12	0.01	3.90	15.21	0.09
52	sll-x	-0.01	-0.08	0.38	0.14	5.89	34.69	0.42
53	slly	-0.06	-0.65	0.29	0.08	4.25	18.06	0.47

Bold * t- value significant at $p < 0.05$ level.
+ 10 < % of total variance < 20.
++ 20 < % of total variance < 30.
+++ % of total variance > 30

5.2 SAMPLE - DIFFERENCES BETWEEN GENDERS

Comparison of mean values for dento-facial variables between males and females were made as followings :

5.2.1 Pre-treatment.
5.2.2 At stage 1 treatment.
5.2.3 Changes (the values at stage 1 minus the pre-treatment values).

5.2.1 Pre-treatment (Table 5)

The mean values for each variable in males and females pre-treatment are shown in Table 5 and the variables that displayed statistically significant gender differences at $p < 0.05$ are shown in bold.

Table 5 Mean values for dento-facial variables in males and females pre-treatment. Bold figures indicate significant difference at $p<0.05$.

no.	variable	pre-treatment-male (n = 32) $(\bar{x} \pm SE)$	pre-treatment-female (n = 53) $(\bar{x} \pm SE)$
1	sna angle (°)	80.2±0.6	80.3±0.6
2	snb angle (°)	76.2±0.5	76.1±0.5
3	sn7 to Downs occlusal plane angle (°)	8.7±0.8	8.7±0.7
4	maxillary plane to Downs occlusal plane angle (°)	7.6±0.7	8.0±0.6
5	mandibular plane to Downs occlusal plane angle (°)	18.6±0.7	18.3±0.5
6	maxillary plane to sn plane angle (°)	7.8±0.5	7.4±0.4
7	mandibular plane to sn plane angle (°)	34.0±0.9	33.7±0.7
8	maxillary plane to mandibular plane angle (°)	26.3±1.0	26.4±0.7
9	upper incisor to sn7 plane angle (°)	110.1±1.4	110.4±1.2
10	upper incisor to maxillary plane (°)	111.1±1.3	111.1±1.1
11	lower incisor to sn7 plane angle (°)	61.3±1.3	57.9±0.9
12	lower incisor to mandibular plane angle (°)	**91.4±1.3**	**95.0±0.8**
13	gonial angle (°)	126.7±1.0	126.6±0.7
14	interincisal angle (°)	131.2±1.7	127.4±1.3
15	upper first molar to sn7 plane angle (°)	77.5±0.9	76.0±0.6
16	upper first molar to maxillary plane angle (°)	78.6±0.8	76.7±0.6
17	lower first molar to sn7 plane angle (°)	76.9±0.9	75.8±0.7
18	lower first molar to mandibular plane angle (°)	75.8±1.1	77.1±0.7
19	distance from articulare point to gnathion point (mm)	**100.6±0.9**	**97.6±0.6**
20	distance from condylion point to gnathion point (mm)	**107.1±0.9**	**104.1±0.6**
21	distance from condylion point to a point (mm)	**82.2±0.8**	**84.5±0.6**
22	upper anterior face height (mm)	**50.2±0.5**	**48.5±0.4**
23	lower anterior face height (mm)	61.6±0.9	60.2±0.6
24	total anterior face height (mm)	**109.7±1.1**	**106.6±0.8**
25	posterior face height (mm)	69.5±1.0	67.9±0.6
26	ratio of lower to total anterior face height	56.1±0.4	56.5±0.3
27	ratio of posterior to total anterior face height	63.5±0.8	63.8±0.8
28	distance from upper incisor to maxillary plane (mm)	28.1±0.4	27.5±0.4
29	distance from lower incisor to mandibular plane (mm)	**36.5±0.5**	**35.1±0.3**
30	distance from upper molar to maxillary plane (mm)	21.2±0.3	20.9±0.3
31	distance from lower molar to mandibular plane (mm)	26.0±0.5	25.6±0.3
32	distance from pronasale to soft tissue gnathion (mm)	**82.3±1.1**	**79.6±0.7**
33	nasolabial angle (°)	132.1±1.8	129.8±1.2
34	labiomental angle (°)	104.6±3.5	106.7±2.3
35	overjet (mm)	7.3±0.4	6.9±0.3
36	overbite (mm)	**4.7±0.4**	**3.6±0.3**
37	Wits (ao/bo) (mm)	3.3±0.4	2.6±0.3

38	distance of b-point along the x-axis (mm)	51.8±1.0	50.1±0.8
39	distance of b-point along the y-axis (mm)	76.2±0.9	74.2±0.7
40	pogonion along x-axis (mm)	52.4±1.1	50.6±0.8
41	pogonion along y-axis (mm)	**87.8±1.0**	**84.6±0.7**
42	inferior aspect upper lip along x-axis (mm)	68.9±0.9	66.3±0.7
43	inferior aspect upper lip along y-axis (mm)	60.6±0.7	59.2±0.5
44	superior aspect lower lip along x-axis (mm)	66.6±1.2	64.7±0.7
45	superior aspect lower lip along y-axis (mm)	**62.3±0.8**	**60.0±0.5**

Normally, the facial skeletal and soft tissue sizes in males were larger than females. The variables that showed statistically significant differences ($p<0.05$) were :

1. The lower incisor inclination.
The lower incisors in females were more proclined than in males.
2. The perpendicular distance of lower incisal edge to mandibular plane.
This was larger in males than in females.
3. Overbite.
The overbite in males was deeper than in females.
4. Maxillary and mandibular length (ar-gn, co-gn, and co-a).
This was larger in males than in females.
5. Upper anterior face height and total anterior face height (uafh, tafh).
These were larger in males than in females.
6. The distance from tip of nose to soft tissue chin, which was also longer in males than in females.
7. The hard tissue chin (pog-y) along the y-axis, and this was longer in males than in females.
8. The distance of lower lip (sll-y) along the y-axis.
This was larger in males than females.

5.2.2 At stage 1 treatment (Table 6)

Table 6 shows the mean values for the dento-facial variables in males and females at stage 1. Bold figures indicating the variables that displayed statistically significant differences at $p<0.05$ between males and females at stage 1.

Table 6 Mean values for dento-facial variables in males and females at stage 1. Bold figures indicate significant difference at $p<0.05$.

no.	variable	stage 1-male (n =32) $(\bar{x} \pm SE)$	stage 1-female (n = 53) $(\bar{x} \pm SE)$
1	sna angle (°)	79.9±0.6	80.0±0.6
2	snb angle (°)	75.4±0.5	75.1±0.5
3	sn7 to Downs occlusal plane angle (°)	16.2±0.8	15.0±0.8
4	maxillary plane to Downs occlusal plane angle (°)	14.3±0.8	14.0±0.8
5	mandibular plane to Downs occlusal plane angle (°)	13.3±0.8	13.6±0.5

6	maxillary plane to sn plane angle (°)	8.2±0.5	8.2±0.4
7	mandibular plane to sn plane angle (°)	35.8±1.0	35.7±0.7
8	maxillary plane to mandibular plane angle (°)	27.6±1.0	27.6±0.7
9	upper incisor to sn7 plane angle (°)	91.7±1.3	93.0±1.0
10	upper incisor to maxillary plane (°)	93.6±1.3	94.1±1.1
11	lower incisor to sn7 plane angle (°)	54.1±1.4	51.8±1.1
12	lower incisor to mandibular plane angle (°)	96.4±1.6	99.5±1.1
13	gonial angle (°)	126.4±1.1	126.0±0.6
14	interincisal angle (°)	142.4±1.8	138.8±1.5
15	upper first molar to sn7 plane angle (°)	67.3±1.3	70.0±1.0
16	upper first molar to maxillary plane angle (°)	69.2±1.2	71.0±1.0
17	lower first molar to sn7 plane angle (°)	81.9±1.1	80.8±0.9
18	lower first molar to mandibular plane angle (°)	68.6±0.9	70.5±0.9
19	distance from articulare point to gnathion point (mm)	**103.6±0.9**	**99.0±0.6**
20	distance from condylion point to gnathion point (mm)	**110.6±0.9**	**105.5±0.6**
21	distange from condylion point to a point (mm)	**85.8±0.8**	**82.7±0.6**
22	upper anterior face height (mm)	**51.6±0.6**	**49.3±0.5**
23	lower anterior face height (mm)	**66.7±1.0**	**63.6±0.4**
24	total anterior face height (mm)	**115.9±1.3**	**110.5±0.6**
25	posterior face height (mm)	**72.8±1.1**	**69.3±0.8**
26	ratio of lower to total anterior face height	57.5±0.4	57.5±0.6
27	ratio of posterior to total anterior face height	62.9±0.8	62.9±0.3
28	distance from upper incisor to maxillary plane (mm)	29.4±0.5	28.4±0.6
29	distance from lower incisor to mandibular plane (mm)	35.1±0.6	33.9±0.4
30	distance from upper molar to maxillary plane (mm)	22.1±0.4	21.3±0.4
31	distance from lower molar to mandibular plane (mm)	28.8±0.6	27.7±0.3
32	distance from pronasale to soft tissue gnathion (mm)	**87.7±1.1**	**83.2±0.6**
33	nasolabial angle (°)	134.2±1.7	130.8±1.2
34	labiomental angle (°)	121.3±2.9	121.7±1.9
35	overjet (mm)	0.9±0.3	1.4±0.2
36	overbite (mm)	0.7±0.2	0.7±0.1
37	Wits (ao/bo) (mm)	0.4±0.4	0.5±0.3
38	distance of b-point along the x-axis (mm)	50.1±1.1	48.9±0.8
39	distance of b-point along the y-axis (mm)	**81.4±0.9**	**76.6±0.7**
40	pogonion along x-axis (mm)	50.5±1.2	49.0±0.9
41	pogonion along y-axis (mm)	**92.9±1.1**	**87.7±0.7**
42	inferior aspect upper lip along x-axis (mm)	65.8±1.0	64.2±0.6
43	inferior aspect upper lip along y-axis (mm)	**63.7±0.7**	**59.9±0.5**
44	superior aspect lower lip along x-axis (mm)	65.0±1.1	62.9±0.7
45	superior aspect lower lip along y-axis (mm)	**64.2±0.8**	**60.7±0.5**

All of the variables that showed differences between males and females at stage 1 were measurements of the facial skeletal and soft tissue size structure. These variables were :

1. Maxillary and mandibular length (ar-gn, co-gn, and co-a).
This was larger in males than females.
2. Upper anterior face height, lower anterior face height, total anterior face height, and posterior face height (uafh, lafh, tafh, pfh).
These were larger in males than females.
3. The distance from tip of nose to soft tissue chin, which was also longer in males than in females.
4. The b-point (b-y) and the hard tissue chin (pog-y) along the y-axis, and these were longer in males than females.
5. The distance of upper and lower lip (iul-y and sll-y) along the y-axis.
This was larger in males than females.

5.2.3 Changes (the value of each variable at stage 1 minus the pre-treatment) (Table 7)

The mean changes (from pre-treatment to stage 1) in males and females are shown in Table 7.

Table 7 Mean changes for each variable with treatment in males and females. Bold figures indicate significant difference at $p<0.05$.

no.	variable	change-male (n = 32) $(\bar{x} \pm SE)$	change-female (n = 53) $(\bar{x} \pm SE)$
1	sna angle (°)	-0.4±0.2	-0.3±0.2
2	snb angle (°)	-0.8±0.2	-1.1±0.1
3	sn7 to Downs occlusal plane angle (°)	7.6±0.6	6.3±0.5
4	maxillary plane to Downs occlusal plane angle (°)	6.7±0.7	6.0±0.5
5	mandibular plane to Downs occlusal plane angle (°)	-5.3±0.6	-4.7±0.5
6	maxillary plane to sn plane angle (°)	0.4±0.3	0.7±0.2
7	mandibular plane to sn plane angle (°)	1.8±0.3	2.0±0.2
8	maxillary plane to mandibular plane angle (°)	1.4±0.4	1.2±0.2
9	upper incisor to sn7 plane angle (°)	-18.4±1.7	-17.4±1.2
10	upper incisor to maxillary plane (°)	-17.5±1.7	-17.0±1.2
11	lower incisor to sn7 plane angle (°)	-7.2±1.2	-6.1±1.1
12	lower incisor to mandibular plane angle (°)	5.0±1.1	5.5±1.1
13	gonial angle (°)	-0.4±0.3	-0.7±0.2
14	interincisal angle (°)	11.1±2.1	11.4±1.7
15	upper first molar to sn7 plane angle (°)	-10.2±1.3	-6.1±1.0
16	upper first molar to maxillary plane angle (°)	-9.4±1.3	-5.7±0.9
17	lower first molar to sn7 plane angle (°)	4.9±1.1	5.0±0.7
18	lower first molar to mandibular plane angle (°)	-7.2±1.1	-6.6±0.8

19	distance from articulare point to gnathion point (mm)	**3.0+0.8**	**1.4+0.2**
20	distance from condylion point to gnathion point (mm)	**3.5+0.4**	**1.4+0.2**
21	distance from condylion point to a point (mm)	1.3+4.0	0.6+0.2
22	upper anterior face height (mm)	**1.4+0.2**	**0.9+0.1**
23	lower anterior face height (mm)	**5.0+0.4**	**3.4+0.2**
24	total anterior face height (mm)	**6.2+4.0**	**3.9+0.2**
25	posterior face height (mm)	**3.3+0.3**	**1.5+0.2**
26	ratio of lower to total anterior face height	1.4+0.2	1.1+0.1
27	ratio of posterior to total anterior face height	-0.6+0.3	-0.9+0.2
28	distance from upper incisor to maxillary plane (mm)	1.3+0.2	0.9+0.2
29	distance from lower incisor to mandibular plane (mm)	-1.4+0.2	-1.2+0.2
30	distance from upper molar to maxillary plane (mm)	0.8+0.2	0.4+0.2
31	distance from lower molar to mandibular plane (mm)	2.8+0.3	2.1+0.2
32	distance from pronasale to soft tissue gnathion (mm)	**5.4+0.4**	**3.7+0.2**
33	nasolabial angle (°)	2.1+1.2	1.0+0.3
34	labiomental angle (°)	16.8+2.5	15.0+1.9
35	overjet (mm)	-6.5+0.5	-5.5+0.4
36	overbite (mm)	**-4.1+0.4**	**-3.0+0.3**
37	Wits (ao/bo) (mm)	-3.0+0.4	-2.1+0.3
38	distance of b-point along the x-axis (mm)	-1.7+0.4	-1.1+0.2
39	distance of b-point along the y-axis (mm)	**5.2+0.4**	**2.4+0.5**
40	pogonion along x-axis (mm)	-2.0+0.4	-1.5+0.2
41	pogonion along y-axis (mm)	**5.1+0.3**	**3.1+0.4**
42	inferior aspect upper lip along x-axis (mm)	-3.1+0.6	-2.1+0.3
43	inferior aspect upper lip along y-axis (mm)	**3.1+0.3**	**0.8+0.2**
44	superior aspect lower lip along x-axis (mm)	-1.6+0.4	-1.7+0.3
45	superior aspect lower lip along y-axis (mm)	**2.0+0.3**	**0.8+0.3**

Those variables that exhibited significant differences in change between males and females were again the sizes of the facial structure. The perpendicular distance from the lower incisal edge to the mandibular plane changed more in males than in females and overbite reduced more in males than in females. Changes in variables that showed significant differences between the sexes were :

1. Overbite.
The overbite decreased more in males than in females.
2. Mandibular length (ar-gn and co-gn).
These increase more in males than in females.
3. Upper anterior face height, lower anterior face height, total anterior face height, and posterior face height (uafh, lafh, tafh, and pfh).
These increase more in males than in females.

4. The distance from tip of nose to soft tissue chin.
The change was greater in males than in females.
5. The b-point (b-y) and the hard tissue chin (pog-y) along the y-axis.
Changes were larger in males than in females.
6. The distance of upper and lower lip (iul-y and sll-y) along the y-axis.
These changes were also larger in males than in females.

5.3 SAMPLE - TREATMENT DIFFERENCES

A comparison between the different treatment approaches, extraction and nonextraction, is shown for two major groups in each sex, male-extraction and male-nonextraction; female-extraction and female-nonextraction. This comparison is then further shown in three subgroups in each group, male-extraction with male-nonextraction pre-treatment, male-extraction with male-nonextraction at stage 1 treatment, male-extraction with male-nonextraction for change and female-extraction with female-nonextraction pre-treatment, female-extraction with female-nonextraction at stage 1, female-extraction with female-nonextraction for change.

5.3.1 Male-extraction and male-nonextraction

5.3.1.1 Male-extraction and male-nonextraction - pre-treatment (Table 8 and Graph 1)

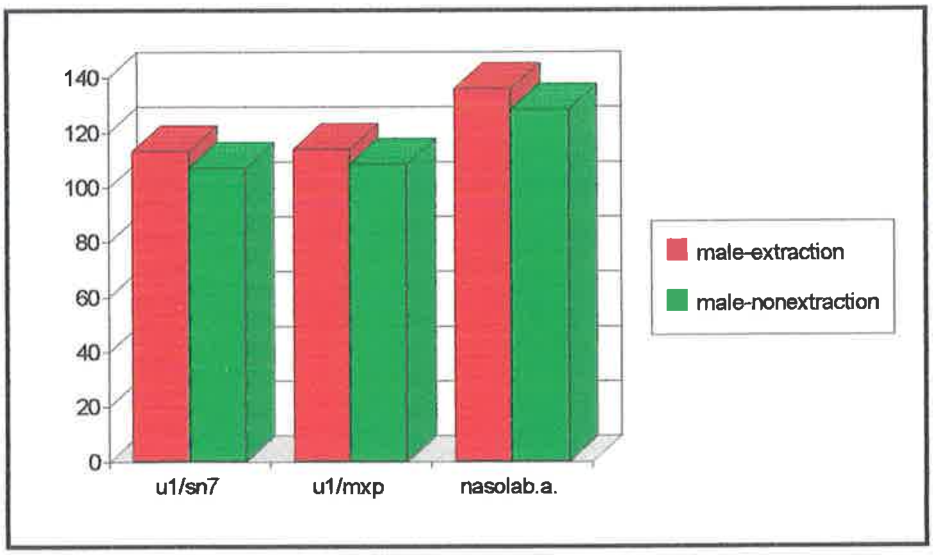
Table 8 Mean values for dento-facial variables in male-extraction and male-nonextraction groups pre-treatment. Bold figures indicate significant difference at $p<0.05$.

no.	variable	male-extraction (n = 15) $(\bar{x} \pm SE)$	male-nonextraction (n = 17) $(\bar{x} \pm SE)$
1	sna angle (°)	79.8±1.0	80.6±0.6
2	snb angle (°)	76.2±0.9	76.1±0.6
3	sn7 to Downs occlusal plane angle (°)	8.2±1.2	9.2±1.1
4	maxillary plane to Downs occlusal plane angle (°)	7.4±1.0	7.9±1.1
5	mandibular plane to Downs occlusal plane angle (°)	20.4±1.1	17.1±0.7
6	maxillary plane to sn plane angle (°)	7.6±0.9	8.0±0.5
7	mandibular plane to sn plane angle (°)	35.4±1.5	32.9±1.1
8	maxillary plane to mandibular plane angle (°)	27.7±1.6	25±1.2
9	upper incisor to sn7 plane angle (°)	**113.2±2.0**	**107.3±1.6**
10	upper incisor to maxillary plane (°)	**114±1.8**	**108.6±1.7**
11	lower incisor to sn7 plane angle (°)	62.3±1.8	60.5±1.9
12	lower incisor to mandibular plane angle (°)	89.2±2.1	93.3±1.7
13	gonial angle (°)	127.5±1.9	126±1.0
14	interincisal angle (°)	129±2.3	133.2±2.4
15	upper first molar to sn7 plane angle (°)	78.7±1.3	76.4±1.2
16	upper first molar to maxillary plane angle (°)	79.5±1.2	77.7±1.2

17	lower first molar to sn7 plane angle (°)	78.2±1.4	75.8±1.1
18	lower first molar to mandibular plane angle (°)	73.2±1.5	78±1.2
19	distance from articulare point to gnathion point (mm)	100.6±1.1	100.6±1.3
20	distance from condylion point to gnathion point (mm)	107±1.4	107.2±1.4
21	distance from condylion point to a point (mm)	83.4±1.4	85.5±1.0
22	upper anterior face height (°)	50.4±0.9	50±0.7
23	lower anterior face height (°)	62.6±1.3	60.8±1.3
24	total anterior face height (°)	110.8±1.6	108.7±1.6
25	posterior face height (°)	69±1.5	70±1.3
26	ratio of lower to total anterior face height	56.4±0.6	55.9±0.6
27	ratio of posterior to total anterior face height	62.4±1.3	64.4±0.9
28	distance from upper incisor to maxillary plane (°)	28.5±0.7	27.6±0.5
29	distance from lower incisor to mandibular plane (°)	36.9±0.8	36.1±0.6
30	distance from upper molar to maxillary plane (°)	21.7±0.5	20.9±0.4
31	distance from lower molar to mandibular plane (°)	25.8±0.8	26.2±0.8
32	distance from pronasale to soft tissue gnathion (mm)	83.4±1.5	81.4±1.5
33	nasolabial angle (°)	**136.1±2.5**	**128.6±2.4**
34	labiomental angle (°)	102.4±4.6	106.5±5.2
35	overjet (mm)	8.1±0.6	6.7±0.6
36	overbite (mm)	4.8±0.4	4.6±0.7
37	Wits (ao/bo) (mm)	3.4±0.6	3.2±0.5
38	distance of b-point along the x-axis (mm)	51.6±1.7	52.1±1.2
39	distance of b-point along the y-axis (mm)	76.9±1.2	75.6±1.3
40	pogonion along x-axis (mm)	52.1±1.8	52.7±1.4
41	pogonion along y-axis (mm)	88.9±1.4	86.9±1.4
42	inferior aspect upper lip along x-axis (mm)	69.9±1.4	67.9±1.2
43	inferior aspect upper lip along y-axis (mm)	60.6±1.1	60.6±0.9
44	superior aspect lower lip along x-axis (mm)	65.8±2.0	67.2±1.4
45	superior aspect lower lip along y-axis (mm)	63.7±1.3	61.0±1.1

Table 8 shows a comparison of mean value for every variable between male-extraction and male-nonextraction pre-treatment. No variables showed statistically significant differences, except variables 17, 18, and 41 (Graph1).

Graph 1 Variables displaying statistically significant differences between male-extraction and male-nonextraction groups pre-treatment, $p<0.05$



Graph 1 showed :

1. The upper incisor in the extraction group was more proclined than in the nonextraction group.
2. The nasolabial angle was more obtuse in the extraction group. However, nasolabial angle is one of the variables that is associated with high percentage error variance (21.22).

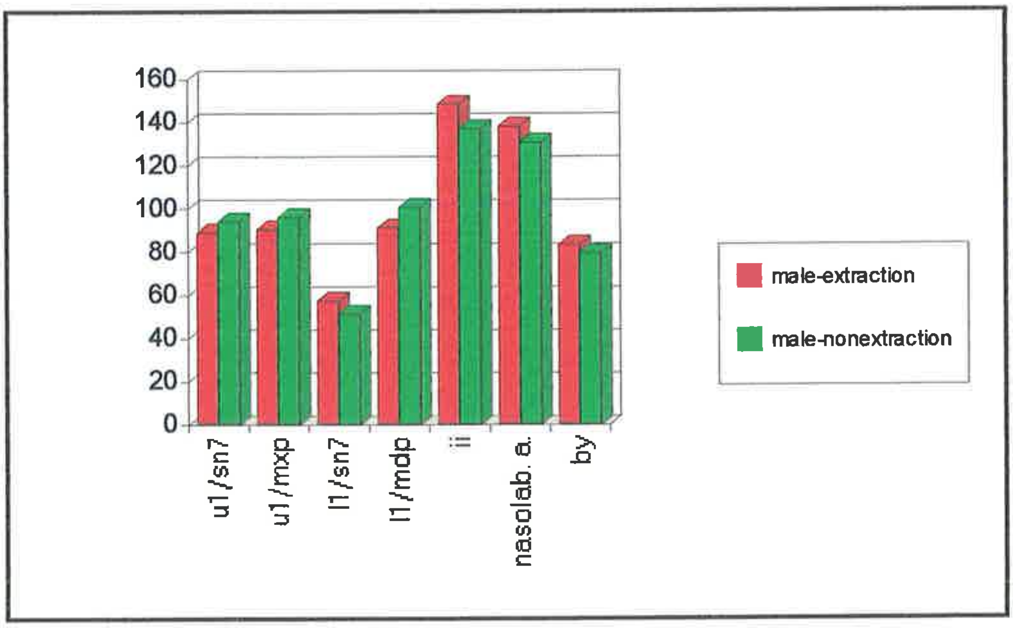
5.3.1.2 Male-extraction and male-nonextraction - at stage 1 (Table 9 and Graph 2)

Table 9 Mean values for dento-facial variables in male-extraction and male-nonextraction groups at stage 1. Bold figures indicate significant difference at $p<0.05$.

no.	variable	male-extraction (n = 15) $(\bar{x} \pm SE)$	male-nonextraction (n = 17) $(\bar{x} \pm SE)$
1	sna angle (°)	79.9±1.2	79.8±0.7
2	snb angle (°)	75.4±1.0	75.3±0.6
3	sn7 to Downs occlusal plane angle (°)	17.2±1.4	15.4±1.0
4	maxillary plane to Downs occlusal plane angle (°)	15.5±4.6	13.3±1.2
5	mandibular plane to Downs occlusal plane angle (°)	14.0±1.3	12.7±1.0
6	maxillary plane to sn plane angle (°)	7.6±0.9	8.8±0.6
7	mandibular plane to sn plane angle (°)	37.1±1.8	34.8±1.0
8	maxillary plane to mandibular plane angle (°)	29.5±1.7	26±1.0
9	upper incisor to sn7 plane angle (°)	**89±1.6**	**94.1±1.8**
10	upper incisor to maxillary plane (°)	**90.6±1.4**	**96.2±2.0**
11	lower incisor to sn7 plane angle (°)	**57.5±2.2**	**51.1±1.3**
12	lower incisor to mandibular plane angle (°)	**91.3±2.3**	**100.8±1.6**
13	gonial angle (°)	127.3±2.0	125.6±1.1

14	interincisal angle (°)	**148.5±2.3**	**137±2.0**
15	upper first molar to sn7 plane angle (°)	69.6±1.8	65.3±1.7
16	upper first molar to maxillary plane angle (°)	71.2±1.6	67.4±1.8
17	lower first molar to sn7 plane angle (°)	80.8±2.0	82.8±0.9
18	lower first molar to mandibular plane angle (°)	68±1.5	69.1±1.1
19	distance from articulare point to gnathion point (mm)	103.7±1.2	103.5±1.5
20	distance from condylion point to gnathion point (mm)	111.2±1.2	110.1±1.4
21	distance from condylion point to a point (mm)	85.3±1.4	86.1±0.8
22	upper anterior face height (mm)	51.9±1.0	51.4±0.7
23	lower anterior face height (mm)	68.2±1.5	65.3±1.2
24	total anterior face height (mm)	117.5±1.9	114.4±1.6
25	posterior face height (mm)	72.9±1.8	72.7±1.5
26	ratio of lower to total anterior face height	58±0.6	57.1±0.5
27	ratio of posterior to total anterior face height	62.2±1.5	63.6±0.9
28	distance from upper incisor to maxillary plane (mm)	30.1±0.8	28.7±0.6
29	distance from lower incisor to mandibular plane (mm)	35.3±0.9	34.9±0.7
30	distance from upper molar to maxillary plane (mm)	22.6±0.5	21.6±0.6
31	distance from lower molar to mandibular plane (mm)	29±1.0	28.6±0.6
32	distance from pronasale to soft tissue gnathion (mm)	88.8±1.7	86.8±1.4
33	nasolabial angle (°)	**138.1±2.6**	**130.7±1.9**
34	labiomental angle (°)	120.9±4.2	121.7±4.3
35	overjet (mm)	1±0.3	0.8±0.4
36	overbite (mm)	0.9±0.2	0.4±0.2
37	Wits (ao/bo) (mm)	0.2±0.6	0.5±0.6
38	distance of b-point along the x-axis (mm)	49±1.9	51.1±1.3
39	distance of b-point along the y-axis (mm)	**83.4±1.4**	**79.6±1.1**
40	pogonion along x-axis (mm)	49.3±2.0	51.5±1.4
41	pogonion along y-axis (mm)	94.7±1.4	91.3±1.5
42	inferior aspect upper lip along x-axis (mm)	64.6±1.7	66.8±1.2
43	inferior aspect upper lip along y-axis (mm)	64.4±1.2	63±0.9
44	superior aspect lower lip along x-axis (mm)	64±1.8	65.8±1.4
45	superior aspect lower lip along y-axis (mm)	64.8±1.2	63.7±1.1

Graph 2 Variables displaying statistically significant differences between male-extraction and male-nonextraction groups at stage 1, p<0.05



Graph 2 showed that at stage 1 treatment :

1. In contrast to the pre-treatment comparisons, the upper incisor in the extraction group was more retroclined than in the nonextraction group after treatment.
2. The lower incisors in the nonextraction group were more proclined than in the extraction group.
3. The interincisal angle in the extraction group was larger than in the nonextraction group.
4. The nasolabial angle in the extraction group was larger than in the nonextraction group.
5. Nasolabial angle in extraction group was more obtuse than in nonextraction group.
6. The b-point showed a larger vertical distance in the male-extraction group than in the male-nonextraction group.

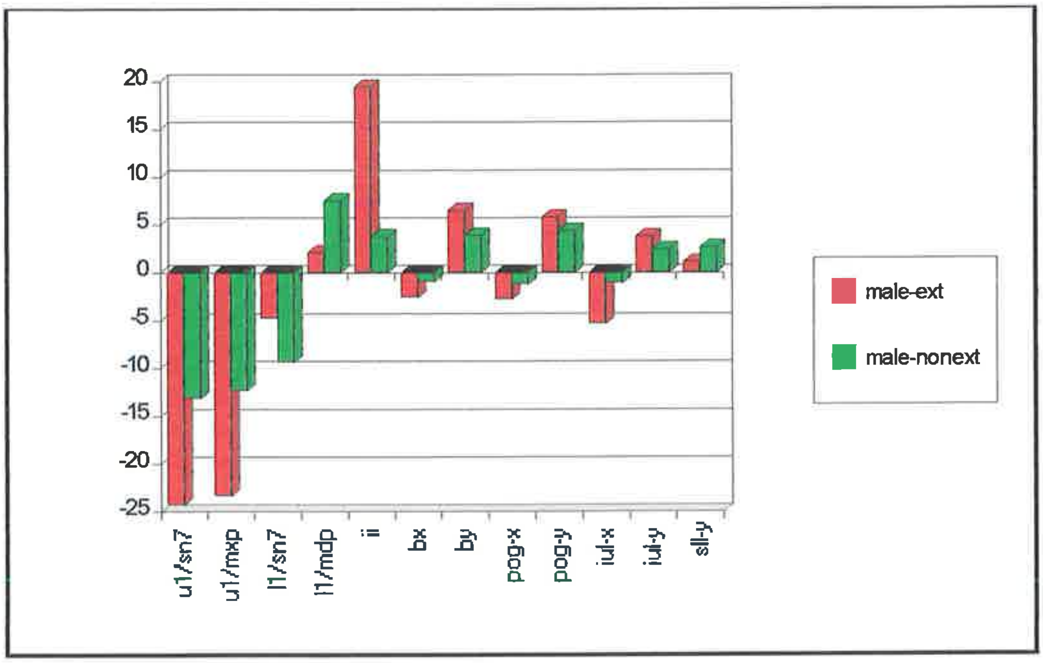
5.3.1.3 Male-extraction and male-nonextraction - changes (Table 10 and Graph 3)

Table 10 Mean changes for each variable with treatment in male-extraction and male-nonextraction groups. Bold figures indicate significant difference at p<0.05.

no.	variable	male-extraction (n = 15) ($\bar{x} \pm SE$)	male-nonextraction (n =17) ($\bar{x} \pm SE$)
1	sna angle (°)	0.1±0.4	-0.8±0.3
2	snb angle (°)	-0.8±0.2	-0.8±0.4
3	sn7 to Downs occlusal plane angle (°)	9.0±0.8	6.2±0.9

4	maxillary plane to Downs occlusal plane angle (°)	8.2±1.0	5.4±1.0
5	mandibular plane to Downs occlusal plane angle (°)	-6.4±0.9	-4.4±0.7
6	maxillary plane to sn plane angle (°)	0±0.4	0.8±0.4
7	mandibular plane to sn plane angle (°)	1.7±0.4	1.9±0.5
8	maxillary plane to mandibular plane angle (°)	1.8±0.6	1.0±0.5
9	upper incisor to sn7 plane angle (°)	**-24.3±2.4**	**-13.2±1.7**
10	upper incisor to maxillary plane (°)	**-23.4±2.3**	**-12.3±1.7**
11	lower incisor to sn7 plane angle (°)	**-4.8±1.2**	**-9.4±1.9**
12	lower incisor to mandibular plane angle (°)	**2.1±1.2**	**7.5±1.7**
13	gonial angle (°)	-0.3±0.5	-0.4±0.4
14	interincisal angle (°)	**19.5±3.0**	**3.8±1.4**
15	upper first molar to sn7 plane angle (°)	-9.2±1.6	-11.1±2.0
16	upper first molar to maxillary plane angle (°)	-8.3±1.7	-10.3±1.9
17	lower first molar to sn7 plane angle (°)	2.5±1.8	7.1±1.2
18	lower first molar to mandibular plane angle (°)	-5.2±1.8	-8.9±1.3
19	distance from articulare point to gnathion point (mm)	3.1±0.4	2.9±0.4
20	distance from condylion point to gnathion point (mm)	4.2±0.5	2.8±0.5
21	distance from condylion point to a point (mm)	1.9±0.6	0.7±0.5
22	upper anterior face height (mm)	1.5±0.2	1.3±0.3
23	lower anterior face height (mm)	5.7±0.5	4.5±0.5
24	total anterior face height (mm)	6.7±0.5	5.7±0.6
25	posterior face height (mm)	3.9±0.4	2.7±0.5
26	ratio of lower to total anterior face height	1.6±0.2	1.2±0.2
27	ratio of posterior to total anterior face height	-0.2±0.3	-0.9±0.5
28	distance from upper incisor to maxillary plane (mm)	1.6±0.4	1.1±0.3
29	distance from lower incisor to mandibular plane (mm)	-1.6±0.3	-1.2±0.2
30	distance from upper molar to maxillary plane (mm)	1.0±0.3	0.7±0.3
31	distance from lower molar to mandibular plane (mm)	3.2±0.3	2.4±0.4
32	distance from pronasale to soft tissue gnathion (mm)	5.4±0.6	5.4±0.6
33	nasolabial angle (°)	2.1±2.0	2.1±1.6
34	labiomental angle (°)	18.6±4.4	15.2±2.6
35	overjet (mm)	-7.1±0.7	-5.9±0.8
36	overbite (mm)	-3.9±0.4	-4.2±0.6
37	Wits (ao/bo) (mm)	-3.2±0.6	-2.7±0.5
38	distance of b-point along the x-axis (mm)	**-2.6±0.5**	**-1.0±0.4**
39	distance of b-point along the y-axis (mm)	**6.5±0.6**	**4.0±0.5**
40	pogonion along x-axis (mm)	**-2.8±0.5**	**-1.3±0.5**
41	pogonion along y-axis (mm)	**5.8±0.5**	**4.4±0.4**
42	inferior aspect upper lip along x-axis (mm)	**-5.3±0.9**	**-1.1±0.6**
43	inferior aspect upper lip along y-axis (mm)	**3.8±0.4**	**2.5±0.4**
44	superior aspect lower lip along x-axis (mm)	-1.8±0.7	-1.4±0.5
45	superior aspect lower lip along y-axis (mm)	**1.1±0.4**	**2.7±0.5**

Graph 3 Variables displaying statistically significant differences in change with treatment between male-extraction and male-nonextraction groups, $p<0.05$



Graph 3 showed that :

1. The upper incisor inclination in the extraction group reduced more than in the nonextraction group.
2. The lower incisor inclination in the nonextraction group proclined more than in the extraction group.
3. The interincisal angle in the extraction group increased more than in the nonextraction group.
4. b-point, pog, and iul showed larger changes in both the vertical and horizontal axes in the extraction group than in the nonextraction group.
5. sll point showed larger changes in the nonextraction group than in the extraction group along the horizontal axis.

5.3.2 Female-extraction and female-nonextraction

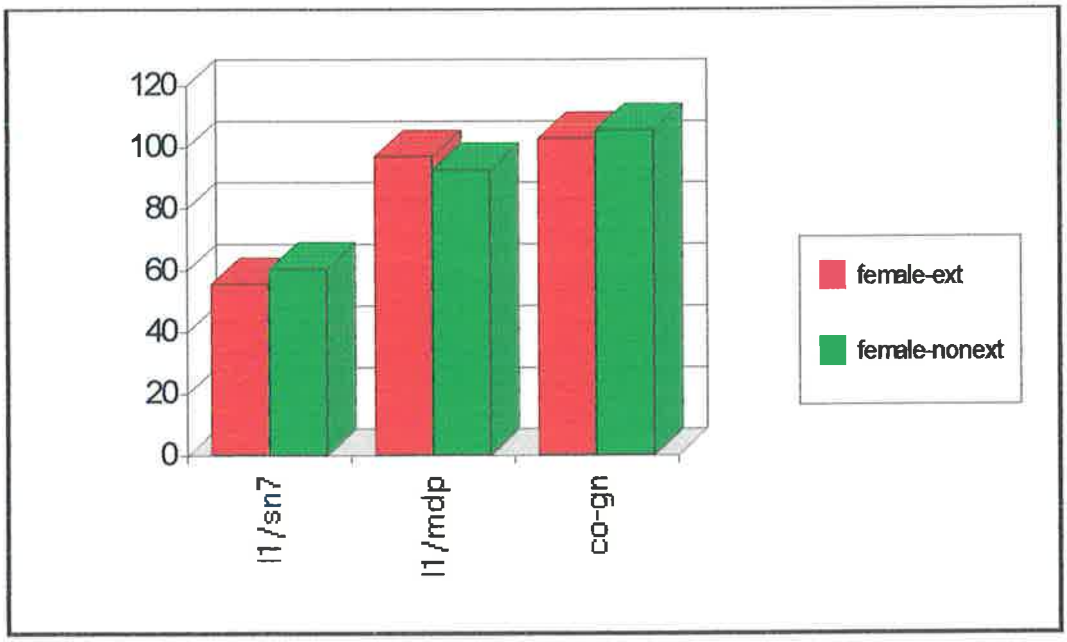
5.3.2.1 Female-extraction and female-nonextraction - pre-treatment (Table 11 and Graph 4)

Table 11 Mean values for dento-facial variables in female-extraction and female-nonextraction groups pre-treatment. Bold figures indicate significant difference at $p<0.05$.

no.	variable	female-extraction (n = 29) $(\bar{x} \pm SE)$	female-nonextraction (n = 24) $(\bar{x} \pm SE)$
1	sna angle (°)	81.0±0.8	79.4±0.9
2	snb angle (°)	76.5±0.7	75.7±0.8
3	sn7 to Downs occlusal plane angle (°)	9.0±0.9	8.5±1.1
4	maxillary plane to Downs occlusal plane angle (°)	8.2±0.9	7.9±0.8
5	mandibular plane to Downs occlusal plane angle (°)	18.4±0.8	18.3±0.5
6	maxillary plane to sn plane angle (°)	7.6±0.6	7.2±0.7
7	mandibular plane to sn plane angle (°)	34.2±1.0	33.3±1.2
8	maxillary plane to mandibular plane angle (°)	26.6±1.0	26.1±0.8
9	upper incisor to sn7 plane angle (°)	111.8±1.6	108.6±1.7
10	upper incisor to maxillary plane (°)	112.6±1.6	109.2±1.3
11	lower incisor to sn7 plane angle (°)	**55.7±1.0**	**60.5±1.5**
12	lower incisor to mandibular plane angle (°)	**97.0±1.2**	**92.7±0.9**
13	gonial angle (°)	126.8±0.8	126.4±1.1
14	interincisal angle (°)	123.8±1.7	131.6±1.7
15	upper first molar to sn7 plane angle (°)	76.4±0.7	75.5±1.0
16	upper first molar to maxillary plane angle (°)	77.2±0.9	76.1±0.8
17	lower first molar to sn7 plane angle (°)	75.5±0.6	76.1±1.5
18	lower first molar to mandibular plane angle (°)	77.1±0.8	77.1±1.2
19	distance from articulare point to gnathion point (mm)	96.9±0.7	98.5±1.0
20	distance from condylion point to gnathion point (mm)	**103.0±0.7**	**105.6±1.1**
21	distance from condylion point to a point (mm)	81.2±0.8	83.3±0.8
22	upper anterior face height (mm)	48.1±0.5	49.0±0.7
23	lower anterior face height (mm)	60.3±0.6	60.1±1.1
24	total anterior face height (mm)	106.0±0.8	107.3±1.5
25	posterior face height (mm)	67.4±0.8	68.5±1.0
26	ratio of lower to total anterior face height	56.9±0.4	56.0±0.5
27	ratio of posterior to total anterior face height	63.6±0.8	64.0±0.9
28	distance from upper incisor to maxillary plane (mm)	27.0±0.4	28.0±0.6
29	distance from lower incisor to mandibular plane (mm)	35.3±0.4	34.8±0.5
30	distance from upper molar to maxillary plane (mm)	20.7±0.3	21.1±0.5
31	distance from lower molar to mandibular plane (mm)	25.9±0.3	25.1±0.6
32	distance from pronasale to soft tissue gnathion (mm)	79.7±0.9	79.4±1.2
33	nasolabial angle (°)	128.9±1.6	130.9±1.9
34	labiomental angle (°)	108.0±2.9	105.0±3.9

35	overjet (mm)	6.5±0.5	7.3±0.4
36	overbite (mm)	3.4±0.3	3.9±0.4
37	Wits (ao/bo) (mm)	2.6±0.4	2.7±0.4
38	distance of b-point along the x-axis (mm)	50.0±1.0	50.1±1.3
39	distance of b-point along the y-axis (mm)	74.1±0.8	74.3±1.2
40	pogonion along x-axis (mm)	50.3±1.1	51.1±1.5
41	pogonion along y-axis (mm)	83.7±0.9	85.5±1.2
42	inferior aspect upper lip along x-axis (mm)	66.4±0.9	66.2±1.1
43	inferior aspect upper lip along y-axis (mm)	58.7±0.6	59.7±0.9
44	superior aspect lower lip along x-axis (mm)	64.5±1.0	64.9±1.1
45	superior aspect lower lip along y-axis (mm)	59.6±0.6	60.4±0.9

Graph 4 Variables displaying statistically significant differences between female-extraction and female-nonextraction groups pre-treatment, $p<0.05$



Graph 4 showed :

1. The lower incisor in the extraction group was more proclined than in the nonextraction group.
2. The mandibular length (co-gn) in the nonextraction group was longer than in the extraction group.

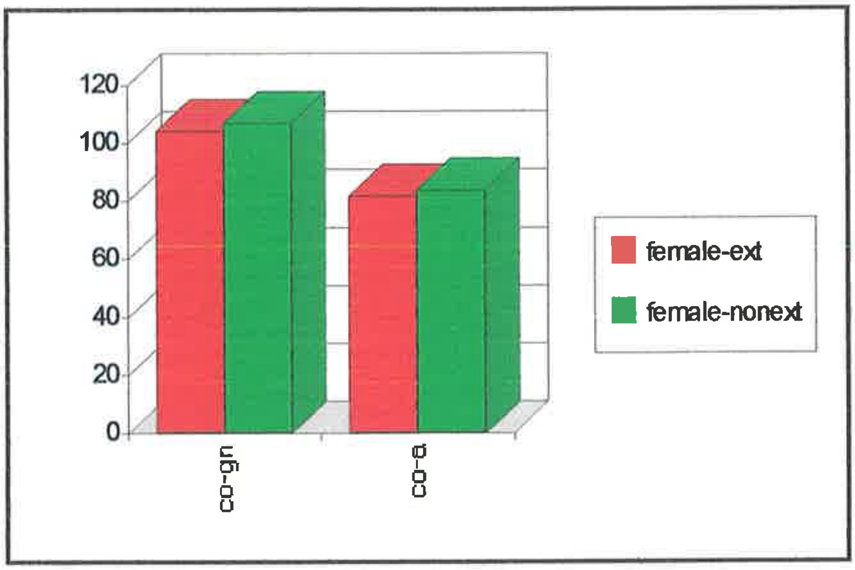
5.3.2.2 Female-extraction and female-nonextraction - at stage 1 (Table 12 and Graph 5)

Table 12 Mean values for dento-facial variables in female-extraction and female-nonextraction groups at stage 1. Bold figures indicate significant difference at $p<0.05$.

no.	variable	female-extraction (n = 29) $(\bar{x} \pm SE)$	female-nonextraction (n = 24) $(\bar{x} \pm SE)$
1	sna angle (°)	80.7±0.8	79.2±0.9
2	snb angle (°)	75.3±0.7	74.7±0.9
3	sn7 to Downs occlusal plane angle (°)	14.3±0.9	16.0±1.2
4	maxillary plane to Downs occlusal plane angle (°)	13.1±1.0	15.1±1.1
5	mandibular plane to Downs occlusal plane angle (°)	14.4±0.8	12.7±0.7
6	maxillary plane to sn plane angle (°)	8.4±0.6	7.8±0.6
7	mandibular plane to sn plane angle (°)	36.0±1.0	35.6±1.2
8	maxillary plane to mandibular plane angle (°)	27.5±1.0	27.8±0.9
9	upper incisor to sn7 plane angle (°)	93.0±1.5	93.1±1.4
10	upper incisor to maxillary plane angle (°)	94.1±1.7	94.0±1.4
11	lower incisor to sn7 plane angle (°)	52.2±1.5	51.2±1.6
12	lower incisor to mandibular plane angle (°)	99.1±1.7	100.1±1.3
13	gonial angle (°)	126.1±0.8	125.8±1.0
14	interincisal angle (°)	139.3±2.5	138.1±1.4
15	upper first molar to sn7 plane angle (°)	71.5±1.4	68.1±1.2
16	upper first molar to maxillary plane angle (°)	72.6±1.6	69.1±1.1
17	lower first molar to sn7 plane angle (°)	80.6±1.0	81.1±1.5
18	lower first molar to mandibular plane angle (°)	70.8±1.2	70.1±1.4
19	distance from articulare point to gnathion point (mm)	98.2±0.8	100.0±1.1
20	distance from condylion point to gnathion point (mm)	**104.3±0.7**	**107.0±1.1**
21	distance from condylion point to a point (mm)	**81.8±0.8**	**83.9±0.6**
22	upper anterior face height (mm)	49.1±2.8	49.7±3.1
23	lower anterior face height (mm)	63.3±3.5	63.9±5.4
24	total anterior face height (mm)	109.7±4.4	111.3±6.8
25	posterior face height (mm)	69.1±4.2	69.6±4.2
26	ratio of lower to total anterior face height	57.7±2.0	57.3±2.4
27	ratio of posterior to total anterior face height	63.0±4.1	62.7±4.1
28	distance from upper incisor to maxillary plane (mm)	27.8±2.1	29.1±3.2
29	distance from lower incisor to mandibular plane (mm)	34.3±2.1	33.4±3.1
30	distance from upper molar to maxillary plane (mm)	21.2±2.1	21.3±2.3
31	distance from lower molar to mandibular plane (mm)	28.1±1.9	27.2±2.6
32	distance from pronasale to soft tissue gnathion (mm)	83.1±4.2	83.4±5.1
33	nasolabial angle (°)	132.0±9.0	129.4±9.0
34	labiomental angle (°)	121.2±11.6	122.3±16.0
35	overjet (mm)	1.4±1.5	1.3±1.2
36	overbite (mm)	0.7±0.8	0.7±0.8
37	Wits (ao/bo) (mm)	0.4±2.0	0.6±2.6

38	distance of b-point along the x-axis (mm)	49.0±5.3	48.8±6.5
39	distance of b-point along the y-axis (mm)	76.5±4.9	76.8±5.3
40	pogonion along x-axis (mm)	48.9±6.2	49.3±7.4
41	pogonion along y-axis (mm)	86.9±4.3	88.6±5.6
42	inferior aspect upper lip along x-axis (mm)	64.3±4.6	64.0±4.6
43	inferior aspect upper lip along y-axis (mm)	59.3±2.9	60.7±3.9
44	superior aspect lower lip along x-axis (mm)	63.3±5.0	62.5±5.6
45	superior aspect lower lip along y-axis (mm)	60.0±3.2	61.6±4.6

Graph 5 Variables displaying statistically significant differences between female-extraction and female-nonextraction groups at stage 1, $p<0.05$



Graph 5 showed that mandibular length (co-gn) and maxillary length (co-a) at stage 1 in female-nonextraction group were still longer than in female-extraction group.

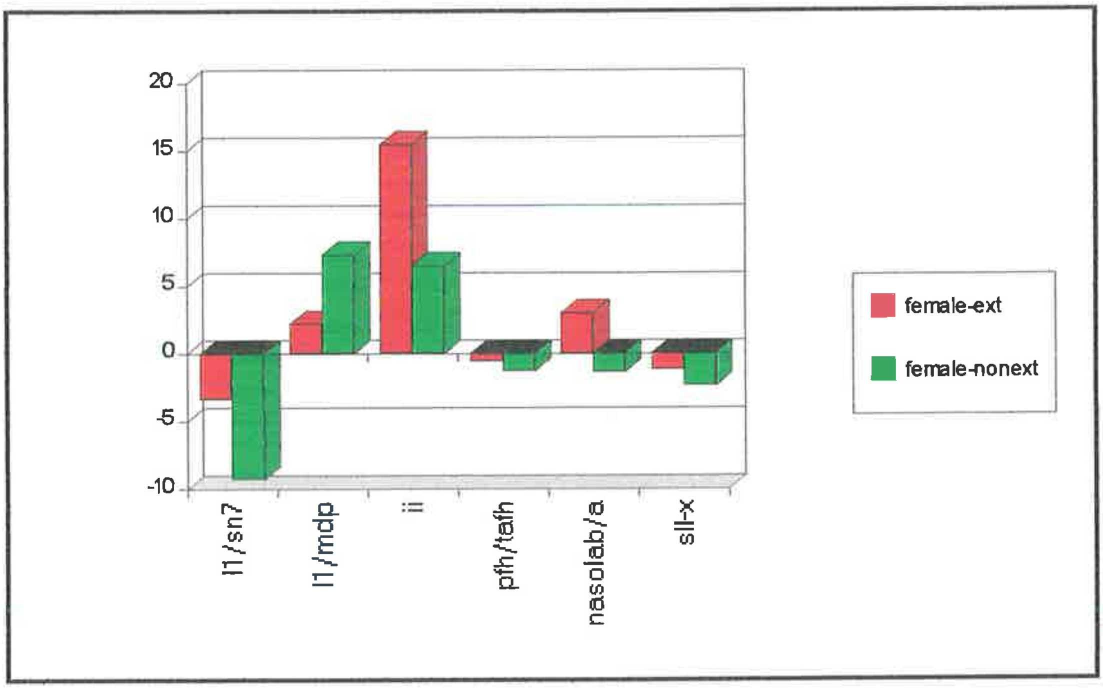
5.3.2.3 Female-extraction and female-nonextraction - changes (Table 13 and Graph 6)

Table 13 Mean changes for each variable with treatment in female-extraction and female-nonextraction groups. Bold figures indicate significant difference at $p<0.05$.

no.	variable	female-extraction (n = 29) $(\bar{x} \pm SE)$	female-nonextraction (n = 24) $(\bar{x} \pm SE)$
1	sna angle (°)	-0.3±0.3	-0.3±0.3
2	snb angle (°)	-1.1±0.2	-1.0±0.2
3	sn7 to Downs occlusal plane angle (°)	5.3±0.6	7.6±0.7
4	maxillary plane to Downs occlusal plane angle (°)	5.0±0.6	7.2±0.7
5	mandibular plane to Downs occlusal plane angle (°)	-4.0±0.6	-5.6±0.6
6	maxillary plane to sn plane angle (°)	0.8±0.2	0.6±0.3
7	mandibular plane to sn plane angle (°)	1.8±0.3	2.3±0.2

8	maxillary plane to mandibular plane angle (°)	0.9±0.3	1.7±0.3
9	upper incisor to sn7 plane angle (°)	-18.9±1.6	-15.6±1.7
10	upper incisor to maxillary plane (°)	-18.5±1.6	-15.2±1.6
11	lower incisor to sn7 plane angle (°)	**-3.4±1.7**	**-9.3±1.1**
12	lower incisor to mandibular plane angle (°)	**2.2±1.7**	**7.3±1.1**
13	gonial angle (°)	-0.7±0.3	-0.6±0.3
14	interincisal angle (°)	**15.4±2.6**	**6.5±1.4**
15	upper first molar to sn7 plane angle (°)	-5.0±1.5	-7.4±1.1
16	upper first molar to maxillary plane angle (°)	-4.5±1.5	-7.0±1.2
17	lower first molar to sn7 plane angle (°)	5.1±0.9	5.0±1.3
18	lower first molar to mandibular plane angle (°)	-6.3±1.0	-7±0.2
19	distance from articulare point to gnathion point (mm)	1.3±0.3	1.4±0.2
20	distance from condylion point to gnathion point (mm)	1.4±0.3	1.5±0.3
21	distance from condylion point to a point (mm)	0.6±0.3	0.6±0.3
22	upper anterior face height (mm)	1.0±0.2	0.7±0.2
23	lower anterior face height (mm)	3.1±0.3	3.7±0.3
24	total anterior face height (mm)	3.7±0.3	4.1±0.4
25	posterior face height (mm)	1.7±0.3	1.2±0.3
26	ratio of lower to total anterior face height	0.9±0.1	1.3±0.2
27	ratio of posterior to total anterior face height	**-0.6±0.3**	**-1.3±0.3**
28	distance from upper incisor to maxillary plane (mm)	0.7±0.3	1.2±0.3
29	distance from lower incisor to mandibular plane (mm)	-1.0±0.2	-1.4±0.3
30	distance from upper molar to maxillary plane (mm)	0.5±0.2	0.2±0.3
31	distance from lower molar to mandibular plane (mm)	2.1±0.2	2.1±0.3
32	distance from pronasale to soft tissue gnathion (mm)	3.3±0.4	4.0±0.4
33	nasolabial angle (°)	**3.0±1.4**	**-1.4±1.2**
34	labiomental angle (°)	13.2±2.2	17.2±3.3
35	overjet (mm)	-5.1±0.5	-6.0±0.5
36	overbite (mm)	-2.7±0.3	-3.3±0.4
37	Wits (ao/bo) (mm)	-2.2±0.3	-2.1±0.5
38	distance of b-point along the x-axis (mm)	-1±0.3	-1.3±0.3
39	distance of b-point along the y-axis (mm)	2.4±0.7	2.5±0.5
40	pogonion along x-axis (mm)	-1.4±0.3	-1.8±0.3
41	pogonion along y-axis (mm)	3.2±0.7	3.1±0.4
42	inferior aspect upper lip along x-axis (mm)	-2.1±0.5	-2.2±0.5
43	inferior aspect upper lip along y-axis (mm)	0.5±0.3	1.0±0.4
44	superior aspect lower lip along x-axis (mm)	-1.2±0.4	-2.4±0.5
45	superior aspect lower lip along y-axis (mm)	**0.4±0.4**	**1.3±0.4**

<u>Graph 6</u> Variables displaying statistically significant differences in change with treatment between female-extraction and female-nonextraction groups, $p<0.05$



Graph 6 showed :

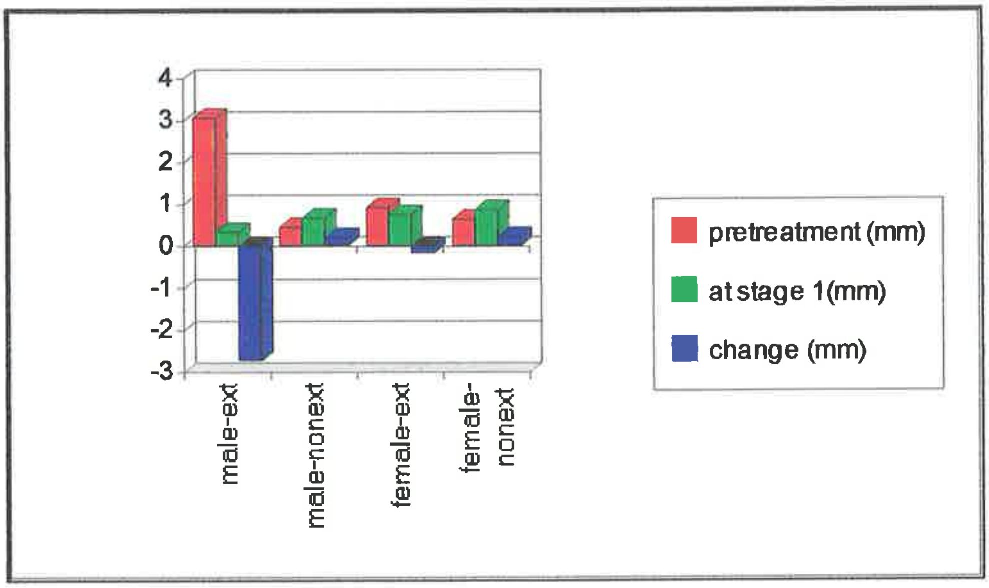
1. The lower incisor in the nonextraction group showed a larger change in proclination direction than in the extraction group.
2. The interincisal angle in the extraction group increased more than in the nonextraction group.
3. The ratio of the posterior face height to the total anterior face height in the nonextraction group decreased more than in the extraction group.
4. The nasolabial angle increased in the extraction group but decreased in the nonextraction group.
5. The lower lip in the nonextraction group showed more change in the horizontal axis than in the extraction group.

5.4 INTERLABIAL GAP

This study showed a reduction of the interlabial gap at stage 1 in the male and female extraction groups, and in the total sample studied as a whole. The male and female nonextraction groups displayed a small increase in the interlabial gap, however, the magnitudes of the increases were not statistically significantly different at the $p<0.05$ level except for the male-extraction group. The results of comparing the pre-treatment interlabial gap to that at stage 1 in each group are shown in Table 14, Graph 7.

Table 14, Graph 7 Interlabial gap of patients pre-treatment, at stage 1, and the mean change. Bold figure indicates significant difference at $p<0.05$.

treatment group (n)	pretreatment (mm) $(\bar{x} \pm SE)$	at stage 1(mm) $(\bar{x} \pm SE)$	change (mm) $(\bar{x} \pm SE)$
all sample (85)	1.13±0.2	0.7±0.2	-0.43±0.3
male-extraction (15)	3.07±0.6	0.36±0.4	**-2.72±0.6**
male-nonextraction (17)	0.47±0.4	0.68±0.4	0.22±0.3
female-extraction (29)	0.92±0.4	0.76±0.3	-0.16±0.5
female-nonextraction (24)	0.65±0.3	0.88±0.4	0.23±0.5



n	=	sample size
all sample	=	85 patients
male-extraction	=	15 patients
male-nonextraction	=	17 patients
female-extraction	=	29 patients
female-nonextraction	=	24 patients
no missing value		

5.5 THE MANDIBULAR PLANE CHANGES

The treatment caused mandibular plane opening in every group. Females tended to show a greater increase in the steepness of mandibular plane angle, variable 7 (mdp/sn7), than males at stage 1 treatment (Table 15, Graph 8).

The male-nonextraction group tended to show a greater increase in the steepness of mandibular plane angle than male-extraction group. Same tendency in females, the female-nonextraction group tended to show a greater increase in the steepness of mandibular plane angle than the female-extraction group (Table 16, Graph 9).

Table 15, Graph 8 Mandibular plane change relative to cranial base (sn plane) in males and females

gender (n)	pretreatment (°) ($\bar{x} \pm SE$)	at stage 1 (°) ($\bar{x} \pm SE$)	change (°) ($\bar{x} \pm SE$)
males (32)	34.0±0.9	35.8±1.0	1.8±0.3
females (53)	33.7±0.7	35.7±0.7	2.0±0.2

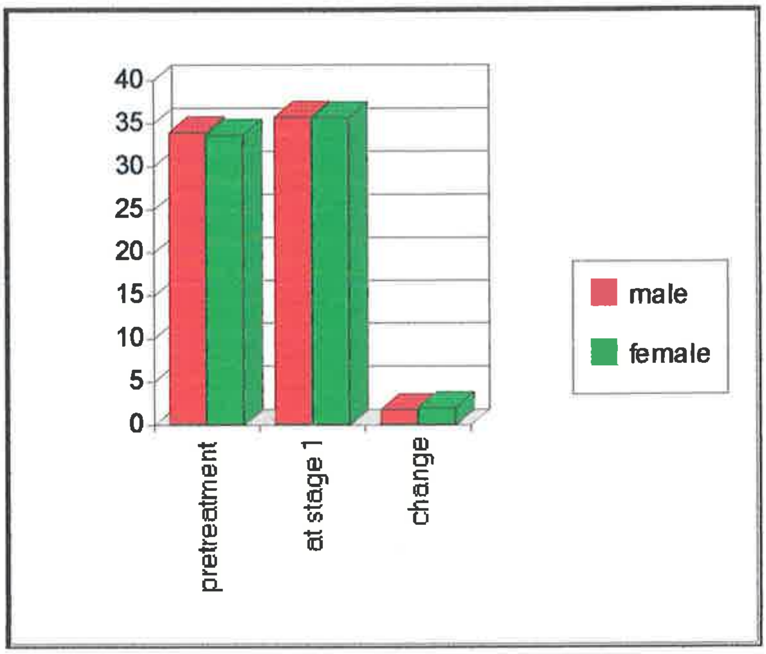
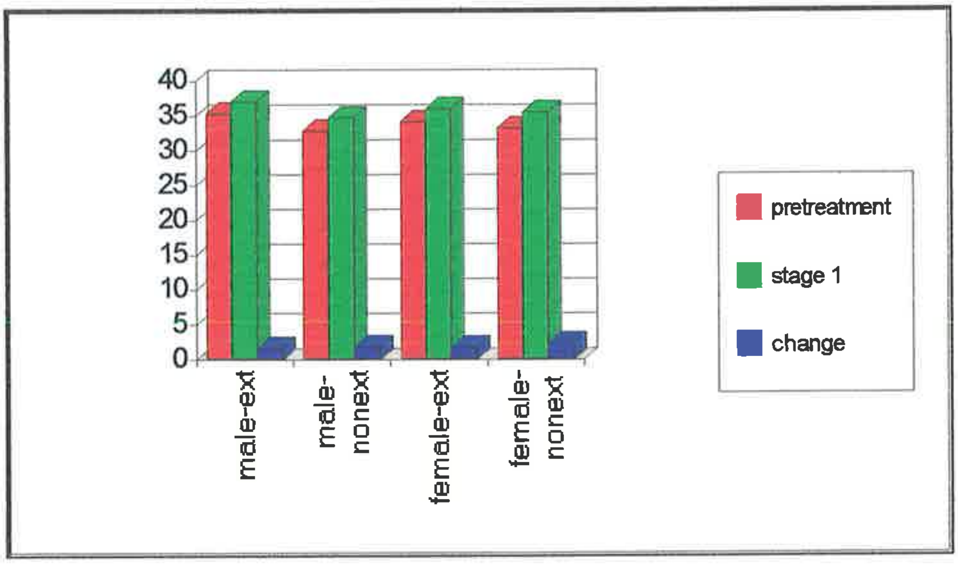


Table 16, Graph 9 Mandibular plane change relative to cranial base (sn plane) in male-extraction, male-nonextraction, female-extraction, and female-nonextraction groups

treatment group (n)	pretreatment (°) $(\bar{x} \pm SE)$	at stage 1 (°) $(\bar{x} \pm SE)$	change (°) $(\bar{x} \pm SE)$
male-extraction (15)	35.4+1.5	37.1+1.8	1.7+0.4
male-nonextraction (17)	32.9+1.1	34.8+1.0	1.9+0.5
female-extraction (29)	34.2+1.0	36.0+1.0	1.8+0.3
female-nonextraction (24)	33.3+1.2	35.6+1.2	2.3+0.2



5.6 THE DOWNS OCCLUSAL PLANE CHANGES

Variable 3 (sn7/dop) represented the Downs occlusal plane. Treatment caused the Downs occlusal plane to open in every patient group (Table 17, Graph 10). Changes of this variable seemed to be opposite to changes of the mandibular plane. The steepness of Downs occlusal plane angle tended to increase more in males than in females at stage 1 treatment.

The male-extraction group showed more opening of mandibular plane angle than the male-nonextraction group while the female-nonextraction group tended to have Downs occlusal plane opening more than the female-extraction group (Table 18, Graph 11).

Table 17, Graph 10 Changes in the Downs occlusal plane in males and females

gender (n)	pretreatment (°) $(\bar{x} \pm SE)$	at stage 1 (°) $(\bar{x} \pm SE)$	change (°) $(\bar{x} \pm SE)$
males (32)	8.7±0.8	16.2±0.8	7.6±0.6
females (53)	8.7±0.7	15.0±0.8	6.3±0.5

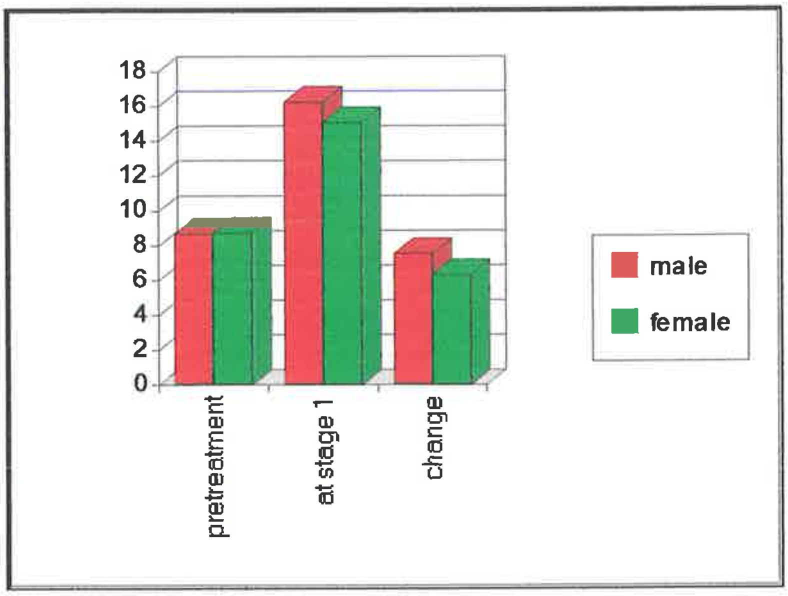
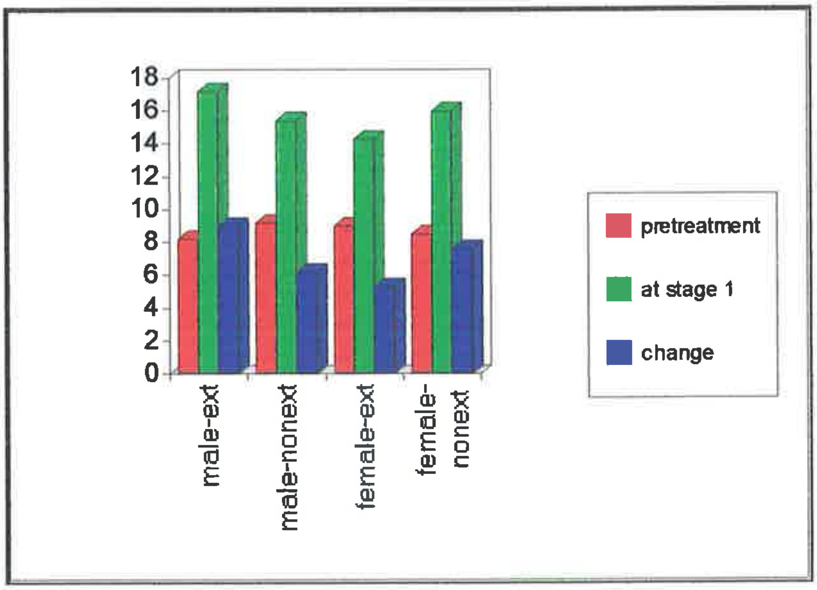


Table 18, Graph 11 Changes in the Downs occlusal plane in male-extraction, male-nonextraction, female-extraction, and female-nonextraction groups

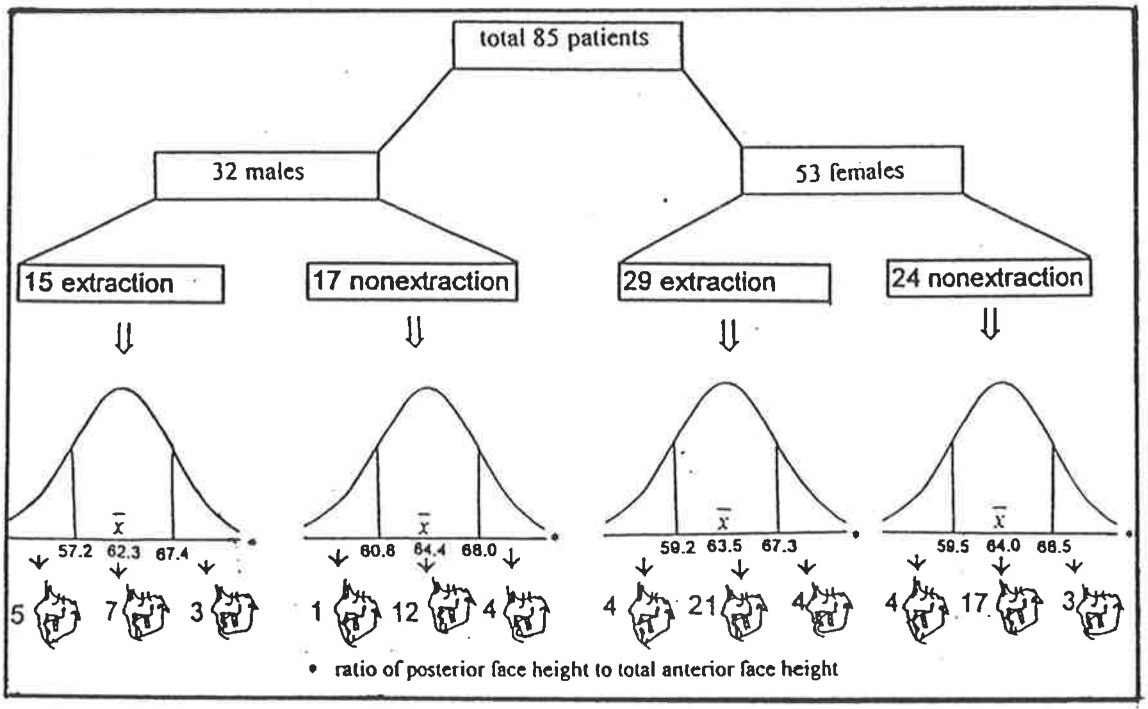
treatment group (n)	pretreatment (°) $(\bar{x} \pm SE)$	at stage 1 (°) $(\bar{x} \pm SE)$	change (°) $(\bar{x} \pm SE)$
male-extraction (15)	8.2±1.2	17.2±1.4	9.0±0.8
male-nonextraction (17)	9.2±1.1	15.4±1.0	6.2±0.9
female-extraction (29)	9.0+0.9	14.3+0.9	5.3+0.6
female-nonextraction (24)	8.5±1.1	16.0±1.2	7.6±0.7



5.7 RESULTS OF CORRELATION ANALYSIS

Comparisons of pre-treatment and stage 1 treatment records for each subject enabled the change in dimension of each craniofacial variable to be quantified. The association between the change in each of the craniofacial variables and face height was then quantified using the product-moment correlation coefficient, r. In addition, for those variables that displayed significant correlations ($p<0.05$), ANOVA was performed to compare the degree of change in craniofacial form between patients grouped according to face height ratio. The three patient groups were defined as following :

Diagram 1 Classification of the samples



1. long-faced group (one standard deviation or more below the average face height ratio).

Male-extraction group included the patients that had a ratio of posterior face height to total anterior face height of less than 57.2 percent from the pre-treatment radiographs.

Male-nonextraction group included the patients that had a ratio of posterior face height to total anterior face height of less than 60.8 percent from the pre-treatment radiographs.

Female-extraction group included the patients that had a ratio of posterior face height to total anterior face height of less than 59.2 percent from the pre-treatment radiographs.

Female-nonextraction group included the patients that had a ratio of posterior face height to total anterior face height of less than 59.5 percent from the pre-treatment radiographs.

2. average group (in the range mean $\pm$ 1 standard deviation, sd)

Male-extraction group included the patients that had a ratio of posterior face height to total anterior face height of between 57.2 to 67.4 percent from the pre-treatment radiographs.

Male-nonextraction group included the patients that had a ratio of posterior face height to total anterior face height of between 60.8 to 68.0 percent from the pre-treatment radiographs.

Female-extraction group included the patients that had a ratio of posterior face height to total anterior face height of between 59.2 to 67.3 percent from the pre-treatment radiographs.

Female-nonextraction group included the patients that had a ratio of posterior face height to total anterior face height of between 59.5 to 68.5 percent from the pre-treatment radiographs.

3. short-faced group (one standard deviation or more above the average face height ratio).

Male-extraction group included the patients that had a ratio of posterior face height to total anterior face height of more than 67.4 percent from the pre-treatment radiographs.

Male-nonextraction group included the patients that had a ratio of posterior face height to total anterior face height of more than 68.0 percent from the pre-treatment radiographs.

Male-extraction group included the patients that had a ratio of posterior face height to total anterior face height of more than 67.3 percent from the pre-treatment radiographs.

Male-extraction group included the patients that had a ratio of posterior face height to total anterior face height of more than 68.5 percent from the pre-treatment radiographs.

The variables that displayed significant associations between the changes in variables and face type (pfh/tafh) according to correlation analysis are shown in Table 19. The average tracings of patients in each group : male-extraction; male-nonextraction; female-extraction; and female-nonextraction at pre-treatment and at stage 1 of treatment, are shown in Appendix 4.

Table 19 Results from correlation analysis of change (at stage 1 - pre-treatment) in dento-facial variables with face height ratio significant correlation ($p<0.05$) indicated only

male-nonextraction	male-extraction	female-nonextraction	female-extraction
v.29 I1-mdp -0.66	v.7 mdp/sn -0.65	v. 27 pfh/tafh -0.44	v. 6 mxp/sn -0.43
	v.25 pfh 0.53	v. 29 I1-mdp -0.65	
		v. 33 nasolab/a -0.42	

5.7.1 Male-nonextraction group

The change in variable 29 (distance from lower incisor to mandibular plane, l1-mdp) displayed a significant negative correlation (r = -0.66, $p<0.05$) with face height ratio (Diagram 2). This means that long-faced patients tended to display greater change in perpendicular distance from the lower incisal edge to the mandibular plane than short-faced patients.

The analysis of variance of variable 29 (distance from lower incisor to mandibular plane, l1-mdp) compared the mean changes between high, average, and low ratio of posterior face height to total anterior face height groups (Table 20).

Diagram 2 Scatter diagram of change in variable 29 (distance from lower incisor to mandibular plane, l1-mdp) with face height ratio in the male-nonextraction patients, $p<0.05$

```
  ++----+----+----+----+----+----+----+----++
 2+                                        +
  |                                        |
  |                                        |
  |                                        |
  R                                        |
 0+       1      2      1                  +
  |                1    1                  |
  |        1     1              1          |
  |               2                        |
  |                  11                    |
-2+                               1  1     +
  |                                  1     R
  |                                        |
  |                                        |
  |                           1            |
-4+                                        +
  |                                        |
  |                                        |
  |                                        |
  |                                        |
-6+                                        +
  ++----+----+----+----+----+----+----+----++
   56        60        64        68        72

              pfh/afh(before)
```

• 1 means one value
• 2 means two values fall on the same point of diagram

Table 20 Mean changes in variable 29 (distance from lower incisor to mandibular plane, l1-mdp) of individuals with high, average, and low ratios of posterior face height to total anterior face height in the male-nonextraction patients

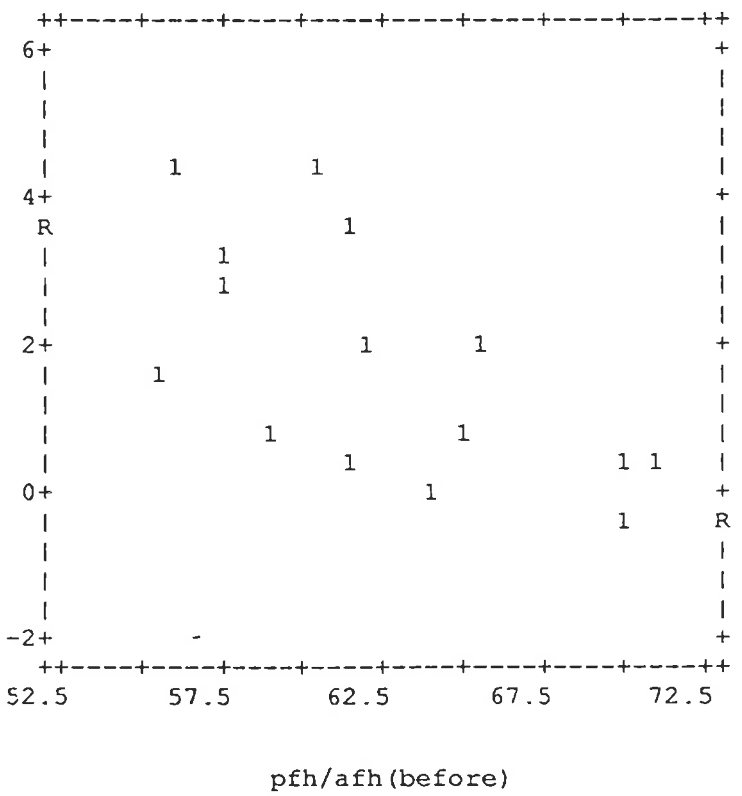
pfh/tafh ratio group	number of patients	mean change
high	4	-1.98mm
average	12	-1.06mm
low	1	-0.04mm

5.7.2 Male-extraction group

The change in variable 7 (mandibular plane to sn plane angle, mdp/sn) displayed a significant negative correlation ($r = -0.65$, $p<0.05$) with face height ratio (Diagram 3). This means that long-faced patients tended to exhibit greater mandibular plane opening than short-faced patients with treatment.

The analysis of variance showed the same pattern of mean changes of each face type group (Table 21).

Diagram 3 Scatter diagram of change in variable 7 (mdp/sn) with face height ratio in the male-extraction patients, $p<0.05$



- 1 means one value
- 2 means two values fall on the same point of diagram

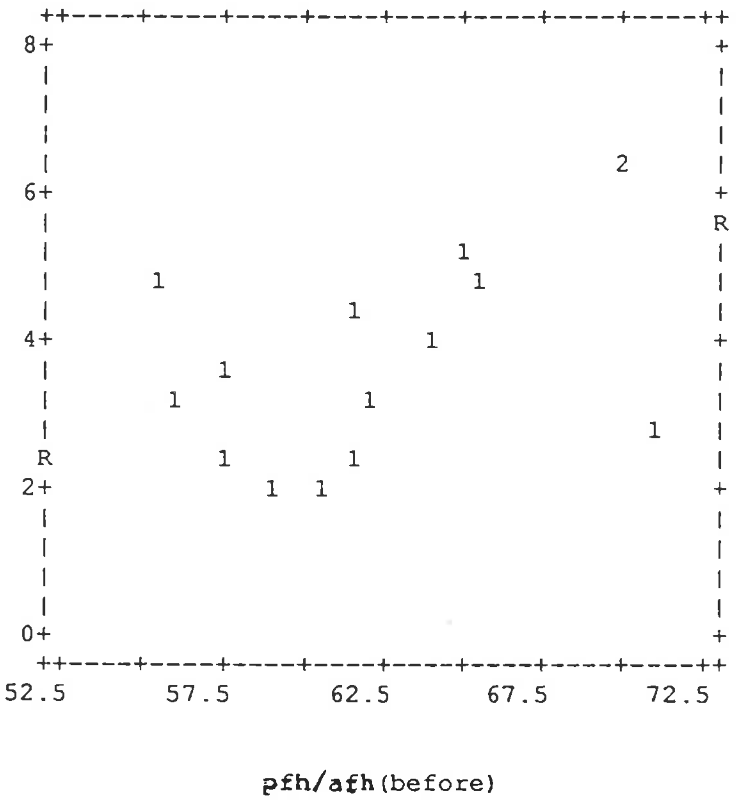
Table 21 Mean changes in variable 7 (mandibular plane to sn plane angle, mdp/sn) of individuals with high, average, and low ratios of posterior face height to total anterior face height in the male-extraction patients

pfh/tafh ratio group	number of patients	mean change
high	3	0.08°
average	7	1.91°
low	5	2.52°

Change in variable 25 (posterior face height, pfh) displayed a significant positive correlation (r = 0.53, $p<0.05$) with face height ratio (Diagram 4). This means that short-faced patients tended to show greater increase in posterior face height (sella-gonion) than long-faced patients during the stage 1 treatment period.

The analysis of variance of variable 25 (posterior face height, pfh) showed the same pattern of mean changes of each face type group (Table 22).

Diagram 4 Scatter diagram of change in variable 25 (pfh) with face height ratio in the male-extraction patients, $p<0.05$



- 1 means one value
- 2 means two values fall on the same point of diagram

Table 22 Mean changes in variable 25 (posterior face height, pfh) of individuals with high, average, and low ratios of posterior face height to total anterior face height in the male-extraction patients

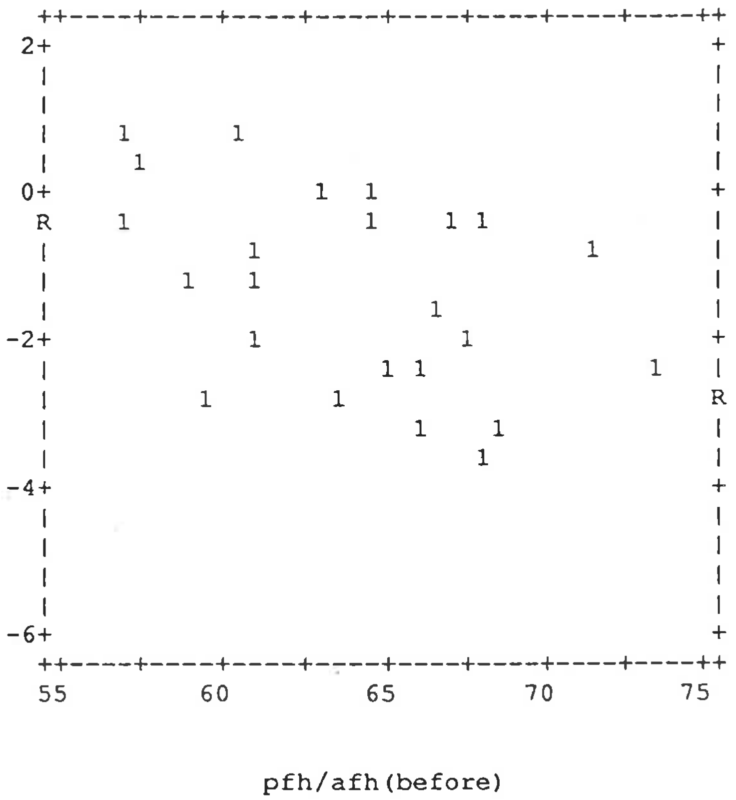
pfh/tafh ratio group	number of patients	mean change
high	3	5.28mm
average	7	3.80mm
low	5	3.21mm

5.7.3 Female-nonextraction group

Change in variable 27 (ratio of posterior face height to total anterior face height, pfh/tafh) displayed a significant negative correlation (r = -0.44, $p<0.05$) with face height ratio (Diagram 5). This means that long-faced patients tended to exhibit greater change than short-faced patients during the treatment.

The analysis of variance of variable 27 (pfh/tafh) showed the same pattern of mean changes of each face type group (Table 23).

Diagram 5 Scatter diagram of change in variable 27 (ratio of posterior face height to total anterior face height, pfh/tafh) with face height ratio in the female-nonextraction patients, $p<0.05$



• 1 means one value
• 2 means two values fall on the same point of diagram

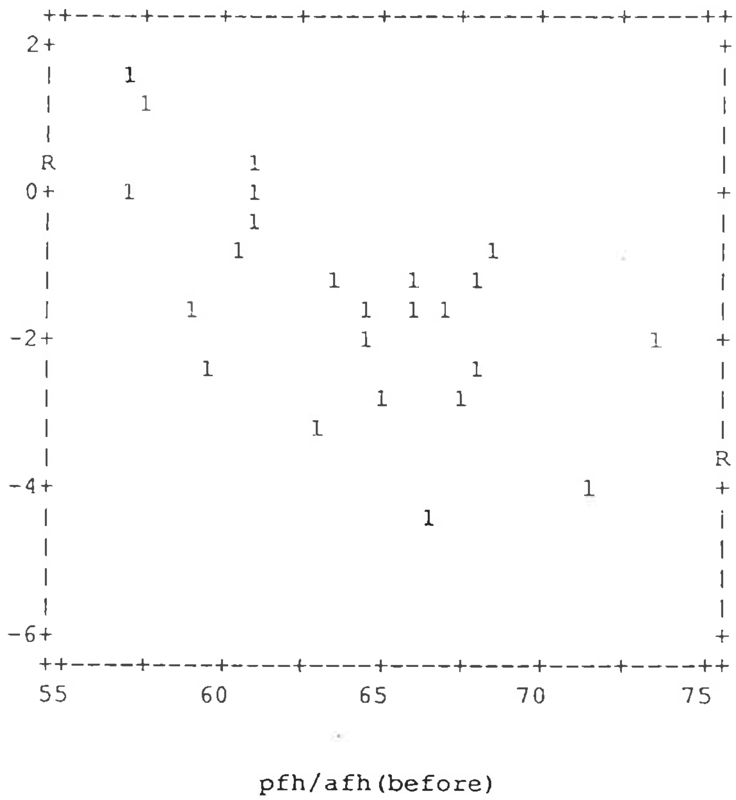
Table 23 Mean changes in variable 27 (ratio of posterior face height to total anterior face height, pfh/tafh) of individuals with high, average, and low ratios of posterior face height to total anterior face height in the female-nonextraction patients

pfh/tafh ratio group	number of patients	mean change
high	3	-2.09
average	17	-1.46
low	4	-0.14

Change in variable 29 (distance from lower incisor to mandibular plane, l1-mdp) displayed a significant negative correlation (r = -0.65, $p<0.05$) with the face height ratio (Diagram 6).

The analysis of variance of variable 29 (l1-mdp) showed the same pattern of mean changes of each face type group (Table 24).

Diagram 6 Scatter diagram of change in variable 29 (distance from lower incisor to mandibular plane, l1-mdp) with face height ratio in the female-nonextraction patients, $p<0.05$



• 1 means one value
• 2 means two values fall on the same point of diagram

Table 24 Mean changes in variable 29 (distance from lower incisor to mandibular plane, l1-mdp) of individuals with high, average, and low ratios of posterior face height to total anterior face height in the female-nonextraction patients

pfh/tafh ratio group	number of patients	mean change
high	3	-2.32mm
average	17	-1.68mm
low	4	0.31mm

Change in variable 33 (nasolabial angle) displayed a significant negative correlation (r = -0.42, p<0.05) with face height ratio (Diagram 7). This means that long-faced patients tended to show greater change of nasolabial angle than short-faced patients with treatment.

The analysis of variance of variable 33 (nasolabial angle) showed the same pattern of mean changes of each face type group (Table 25).

Diagram 7 Scatter diagram of change in variable 33 (nasolabial angle, nasolab/a) with face height ratio in the female-nonextraction patients, p<0.05

```
   ++----+----+----+----+----+----+----+----++
 20+                                         +
   I                                         I
   I                                         I
   I                                         I
   I                                         I
 10+                                         +
   I    1                                    I
   I     1      2                            I
   R           1     1                       I
   I    1    1                               I
  0+                   1  1  11              +
   I                       1             1   I
   I                   1  1 1        1       I
   I                1                        I
   I            1                            R
-10+        1               11               +
   I                    1                    I
   I                                         I
   I                                         I
   I                                         I
-20+                                         +
   ++----+----+----+----+----+----+----+----++
   55        60        65        70        75

              pfh/afh(before)
```

• 1 means one value
• 2 means two values fall on the same point of diagram

Table 25 Mean changes in variable 33 (nasolabial angle, nasolab/a) of individuals with high, average, and low ratios of posterior face height to total anterior face height in the female-nonextraction patients

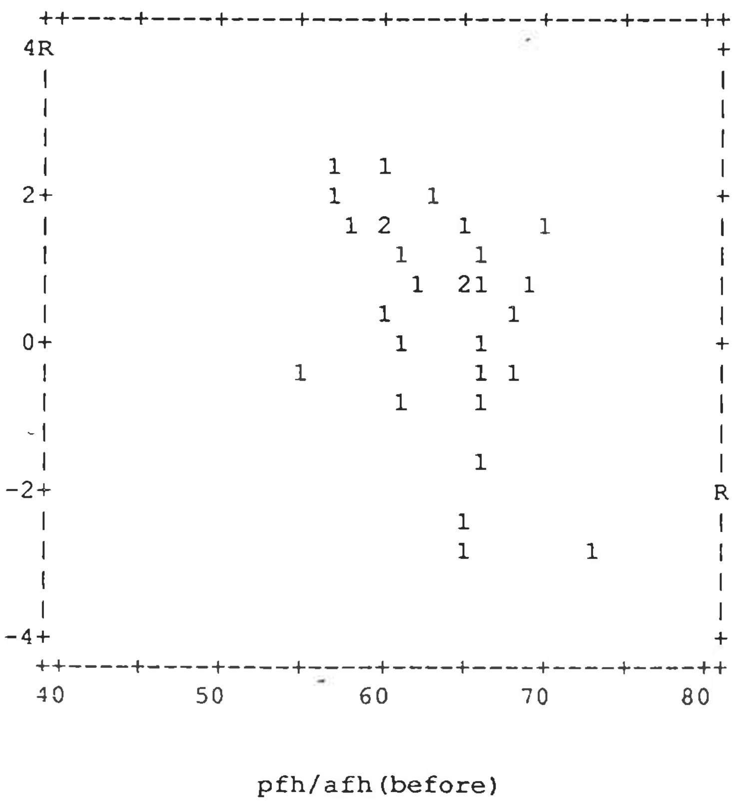
pfh/tafh ratio group	number of patients	mean change
high	3	-1.62°
average	17	-2.15°
low	4	1.79°

5.7.4 Female-extraction group

Change in variable 6 (maxillary plane to sn plane angle, mxp/sn) displayed a significant negative correlation (r = -0.43, $p<0.05$) with face height ratio (Diagram 8).

The analysis of variance of variable 6 (mxp/sn) showed the same pattern of mean changes of each face type group (Table 26).

Diagram 8 Scatter diagram of change in variable 6 (maxillary plane to sn plane angle, mxp/sn) with face height ratio in the female-extraction patients, $p<0.05$



• 1 means one value
• 2 means two values fall on the same point of diagram

Table 26 Mean changes in variable 6 (maxillary plane to sn plane angle, mxp/sn) of individuals with high, average, and low ratios of posterior face height to total anterior face height in the female-extraction patients

pfh/tafh ratio group	number of patients	mean change
high	4	0.59°
average	21	0.69°
low	4	1.78°

5.8 COMPARISON OF THE RESULTS FROM THE PRESENT STUDY WITH PUBLISHED LONGITUDINAL GROWTH STUDIES

Tables 27 and 28 show the results for the male patients in the present study compared with other longitudinal growth studies : the Michigan (Riolo et al., 1974) and the Bhatia and Leighton (1993) longitudinal growth studies. The results of this study were compared to the data from both of the longitudinal growth studies by taking the average value of each variable at 13 years of age from the growth studies and then comparing this with the pre-treatment stage of the present study, and corresponding the average value of each variable from 14 years of age from the growth studies with the result at stage 1 for this study. All of the values of each variable have been adjusted for the enlargement.

Some of the cephalometric measurements used in the present study are similar to those used by the Michigan longitudinal growth study and some are similar to the Bhatia and Leighton longitudinal growth study. However, some of the reference planes differ e.g. the mandibular plane from the Bhatia and Leighton longitudinal growth study used gonion to menton line to represent the mandibular plane but the present study used gonion to gnathion line as the mandibular plane.

The mean value measurements of some variables in the present study from pre-treatment radiograph are closer to the Bhatia and Leighton than the Michigan longitudinal growth studies. This is possibly due to the Bhatia and Leighton growth study's inclusion of many types of malocclusions, 30 Class I, 24 Class II division 1, 3 Class III, and 1 Class II division 2 malocclusion in their 58 male samples and 35 Class I, 18 Class II division 1, 3 Class III, and 7 Class II division 2 malocclusion in their 63 female samples, while the Michigan longitudinal growth study used only 47 male Class I and 36 female Class I normal occlusion in their growth study.

Table 27 Comparison of the results for males in the present study with the published Michigan, and the published Bhatia and Leighton longitudinal growth studies

variables	time	Michigan	Bhatia and Leighton	Present study
sna	pretreatment	81.2±3.4	80.5±4.0	80.2±3.2
	at stage 1	80.7±3.4	80.7±4.1	79.9±3.6
	change	**-0.5**	**0.2**	**-0.3**
snb	pretreatment	77.5±3	77.4±3.9	76.2±3.0
	at stage 1	77.3±3.1	77.6±3.9	75.4±3.0
	change	**-0.2**	**0.2**	**-0.8**
anb	pretreatment	3.7±2	3.1±2.4	4.0±1.6
	at stage 1	3.4±2	3.0±2.5	4.5±2.2
	change	**-0.3**	**-0.1**	**+0.5**
sn/dop	pretreatment	15.6±3.8		8.7±4.5
	at stage 1	15.4±3.9		16.3±4.7
	change	**-0.2**		**7.6**

variables	time	Michigan	Bhatia and Leighton	Present study
mxp/dop	pretreatment	8.5±3		7.6±4.2
	at stage 1	8.3±3.3		14.3±4.8
	change	**-0.2**		**6.7**
sn/mxp	pretreatment	7.1±3.2	6.6±3.1	7.8±2.8
	at stage 1	7.3±3.5	6.9±3.0	8.9±3.0
	change	**0.2**	**0.3**	**1.1**
sn/mdp	pretreatment	32.9±4.8	35.1±5.5	34.1±5.3
	at stage 1	32.9±5	34.9±5.7	35.9±5.6
	change	**0.0**	**-0.2**	**1.8**
mxp/mdp	pretreatment	26±5.3	28.5±5.4	26.3±5.6
	at stage 1	25.9±4.9	28.0±5.5	27.6±5.7
	change	**-0.1**	**-0.5**	**1.3**
u1/sn	pretreatment	103.3±5.9	102.5±7.4	117.1±7.7
	at stage 1	102.6±6	102.3±7.7	98.7±7.3
	change	**-0.7**	**-0.2**	**-18.4**
u1/mxp	pretreatment	110.4±5.7	109.3±7.2	111.1±7.6
	at stage 1	109.9±5.4	109.4±7.7	93.6±7.5
	change	**-0.5**	**0.1**	**-17.5**
l1/mdp	pretreatment	96.3±6.9	91.8±7.4	91.4±7.6
	at stage 1	94.9±7.2	91.8±7.4	96.4±9.0
	change	**-1.4**	**0.0**	**5.0**
ar/go/gn	pretreatment	125.8±5	129.9±4.6	126.7±5.8
	at stage 1	124.0±5.3	129.6±4.5	126.4±6.3
	change	**-1.8**	**-0.3**	**-0.3**
ii	pretreatment	127.6±10.9	130.3±10.3	131.3±9.7
	at stage 1	129.6±10.8	130.7±10.4	142.4±10.1
	change	**2.0**	**0.4**	**11.1**
u6-mxp	pretreatment	21.1±2.1	20.8±1.8	21.2±1.9
	at stage 1	22.0±2.3	21.8±2.1	22.1±2.3
	change	**0.9**	**1.0**	**0.9**
u1-mxp	pretreatment	27.4±2.1	27.0±2.4	28.1±2.5
	at stage 1	28.0±2.0	27.4±2.5	29.4±2.7
	change	**0.6**	**0.4**	**1.3**
l6-mdp	pretreatment	30.0±2.7	27.2±2.8	26.0±3.0
	at stage 1	31.4±2.7	28.2±2.9	28.8±3.2
	change	**1.4**	**1.0**	**2.8**
l1-mdp	pretreatment	39.2±2.8	36.9±2.9	36.5±2.8
	at stage 1	40.5±3.2	37.9±3.1	35.1±3.2
	change	**1.3**	**1.0**	**-1.4**
ar-gn	pretreatment	102.8±4.5	101.3±4.7	100.6±4.9
	at stage 1	105.4±4.6	104.3±4.9	103.6±5.3
	change	**2.6**	**3.0**	**3.0**
co-gn	pretreatment	109.2±4.9	107.5±5	107.1±5.3
	at stage 1	112.2±5.1	110.7±5.1	110.6±5.3
	change	**3.0**	**3.2**	**3.5**
co-a	pretreatment		82.5±4	84.5±4.8
	at stage 1		84.3±4.3	85.8±4.4
	change		**1.8**	**1.3**
uafh	pretreatment	50.4±3.3	50.2±2.5	50.2±3.0
	at stage 1	51.6±3.6	51.6±2.5	51.6±3.2
	change	**1.2**	**1.4**	**1.4**

variables	time	Michigan	Bhatia and Leighton	Present study
lafh	pretreatment	63.9±5.0	61.7±4.9	61.6±5.1
	at stage 1	65.9±5.1	63.3±5.1	66.7±5.5
	change	**2.0**	**1.6**	**5.1**
tafh (N-Me)	pretreatment	112.3±6.2	110.6±6.3	109.7±6.4
	at stage 1	115.6±7.0	113.6±6.4	115.9±7.1
	change	**3.3**	**3.0**	**6.2**
pfh (S-Go)	pretreatment	71.3±5.4	69.9±4.3	69.6±5.5
	at stage 1	73.6±5.0	72.3±4.7	72.8±6.4
	change	**2.3**	**2.4**	**3.2**
lafh/tafh	pretreatment		0.56±5.6	0.56±2.3
	at stage 1		0.56±5.8	0.58±2.1
	change		**0.00**	**0.02**
pfh/afh (S-Go/N-Me)	pretreatment		0.63±5.3	0.63±4.4
	at stage 1		0.63±5.6	0.63±4.7
	change		**0.00**	**0.00**
nasolabial angle	pretreatment		111.3±8.7	132.1±10.3
	at stage 1		110.3±9.6	134.2±9.6
	change		**-1.0**	**2.1**
overjet	pretreatment		4.0±1.5	7.4±2.4
	at stage 1		3.8±1.5	0.9±1.6
	change		**-0.2**	**-6.5**
overbite	pretreatment		3.1±1.5	4.7±2.2
	at stage 1		3.1±1.5	0.7±0.9
	change		**0.0**	**-4.0**

Table 28 Comparison of the results for females in the present study with the published Michigan, and the published Bhatia and Leighton longitudinal growth studies

variables	time	Michigan	Bhatia and Leighton	Present study
sna	pretreatment	81.0±3.8	80.0±3.6	80.3±4.4
	at stage 1	81.3±3.5	80.0±3.8	80.0±4.3
	change	**0.3**	**0.0**	**-0.3**
snb	pretreatment	77.5±3.9	77.8±3.6	76.1±3.8
	at stage 1	77.9±3.8	77.9±3.8	75.1±3.9
	change	**0.4**	**0.1**	**-1.0**
anb	pretreatment	3.5±2.4	2.5±2.5	4.2±2.0
	at stage 1	3.4±2.5	2.3±2.5	5.0±2.1
	change	**-0.1**	**-0.2**	**+0.8**
sn/dop	pretreatment	15.0±4.0		8.7±5.2
	at stage 1	15.7±4.0		15.1±5.6
	change	**0.7**		**6.4**
mxp/dop	pretreatment	6.8±3.2		8.0±4.6
	at stage 1	7.7±3.7		14.0±5.5
	change	**0.9**		**6.0**
sn/mxp	pretreatment	8.2±2.9	7.8±3.8	7.4±3.1
	at stage 1	8.1±1.8	8.0±4.0	7.1±3.0
	change	**-0.1**	**0.2**	**-0.3**

variables	time	Michigan	Bhatia and Leighton	Present study
sn/mdp	pretreatment	34.2+5.4	35.1+5.7	33.8+5.4
	at stage 1	33.5+6.0	34.7+6.0	35.8+5.4
	change	**-0.7**	**-0.4**	**2.0**
mxp/mdp	pretreatment	27.0+3.2	27.2+5.3	26.4+4.8
	at stage 1	25.4+5.18	26.7+5.6	27.6+5.0
	change	**-1.6**	**-0.5**	**1.2**
u1/sn	pretreatment	103.9+5.6	101.5+7.3	110.4+8.4
	at stage 1	104.0+6.2	101.3+7.3	93.0+7.5
	change	**0.1**	**-0.2**	**-17.4**
u1/mxp	pretreatment	112.1+5.7	109.5+7.2	111.1+7.8
	at stage 1	112.1+6.1	109.5+6.9	94.1+8.0
	change	**0.0**	**0.0**	**-1.7**
l1/mdp	pretreatment	93.3+5.7	90.1+6.7	95.0+6.03
	at stage 1	94.5+6.9	89.7+6.8	99.5+7.8
	change	**1.2**	**-0.4**	**4.5**
ar/go/gn	pretreatment	126.1+5.9	130+4.4	126.6+4.8
	at stage 1	125.0+4.7	129.4+4.5	126.0+4.5
	change	**-1.1**	**-0.6**	**-0.6**
ii	pretreatment	128.6+8.4	133.6+10	127.3+9.5
	at stage 1	128.0+9.5	134.7+10	138.8+10.7
	change	**-0.6**	**1.1**	**11.5**
u6-mxp	pretreatment	20.3+2.0	20.1+1.9	20.9+2.1
	at stage 1	20.7+1.8	20.8+1.9	21.3+2.2
	change	**0.4**	**0.7**	**0.4**
u1-mxp	pretreatment	25.2+2.3	26.0+2.7	27.5+2.6
	at stage 1	25.8+2.7	26.3+2.7	28.4+2.7
	change	**0.6**	**0.3**	**0.9**
l6-mdp	pretreatment	27.9+2.0	26.7+2.5	25.6+2.2
	at stage 1	28.7+2.1	27.5+2.5	27.7+2.3
	change	**0.8**	**0.8**	**2.1**
l1-mdp	pretreatment	37.3+2.3	35.8+2.7	35.1+2.4
	at stage 1	37.4+2.3	36.2+2.7	33.9+2.6
	change	**0.1**	**0.4**	**-1.2**
ar-gn	pretreatment	98.8+4.6	99.7+4.2	97.6+4.5
	at stage 1	100.5+4.7	101.3+4.0	99.0+4.7
	change	**1.7**	**1.6**	**1.4**
co-gn	pretreatment	104.5+3.8	107.5+5.0	104.1+4.7
	at stage 1	106.3+3.6	110.7+5.1	105.5+4.7
	change	**1.8**	**3.2**	**1.4**
co-a	pretreatment		80.6+3.0	82.2+4.2
	at stage 1		81.5+2.9	82.7+3.9
	change		**0.9**	**0.5**
uafh	pretreatment	48.5+2.9	49.0+2.7	48.5+3.1
	at stage 1	49.1+2.4	49.7+2.8	49.4+2.9
	change	**0.6**	**0.7**	**0.9**
lafh	pretreatment	60.4+4.0	60.1+5	60.2+4.4
	at stage 1	61.3+4.4	60.9+5	63.6+4.4
	change	**0.9**	**0.8**	**3.4**
tafh (N-Me)	pretreatment	107.1+5.1	108.0+5.7	106.6+5.9
	at stage 1	108.5+5.2	109.5+5.8	110.5+5.6
	change	**1.4**	**1.5**	**3.9**

variables	time	Michigan	Bhatia and Leighton	Present study
pfh (S-Go)	pretreatment	66.4±3.9	68.5±4.4	67.9±4.5
	at stage 1	68.0±4.9	69.9±4.2	69.3±4.1
	change	**1.6**	**1.4**	**1.4**
lafh/tafh	pretreatment		0.56±5.4	0.56±2.2
	at stage 1		0.56±5.4	0.58±2.2
	change		**0.00**	**0.02**
pfh/afh (S-Go/N-Me)	pretreatment		0.63±5.1	0.64±4.3
	at stage 1		0.63±5.0	0.63±4.0
	change		**0.00**	**-0.01**
nasolab. angle	pretreatment		110.5±11.0	129.8±8.8
	at stage 1		109.7±10.2	130.8±9.0
	change		**-0.8**	**1.0**
overjet	pretreatment		3.5±1.2	6.9±2.3
	at stage 1		3.4±1.1	1.4±1.4
	change		**-0.1**	**-5.5**
overbite	pretreatment		3.1±1.7	3.6±1.9
	at stage 1		3.1+1.7	0.7+0.8
	change		**0.0**	**-2.9**

CHAPTER 6 : DISCUSSION

6.1 SAMPLE SIZE

The total sample of 85 individuals for the present study seemed adequate initially, but after division according to face type, some groups included small sample sizes. This resulted in greater uncertainty within these groups when statistical analyses were performed.

6.2 AGE OF PATIENTS

The patients in the present study had an age range from 10.5 to 16.0 years in females, with an average of 13.67 years. The range of ages in males was from 12.2 to 15.5 years, with an average age of 13.5 years. In these age ranges, some patients were in the pre-pubertal growth spurt, some at the peak of the pubertal growth spurt, and some had passed the pubertal growth spurt. Thus the results of the present study illustrate the effect of growth combined with treatment. The treatment effect only may be indicated by comparing the result from the present study with the data from longitudinal growth studies. However, it must be remembered that each individual is different.

6.3 TREATMENT TIME

The treatment time on average was 1.15 years (1 year 2 months). The average for each group was :

- female-extraction 1.17 years, 1 year 2 months, from 0.59 to 2.42 years,
- female-nonextraction 1.26 years, 1 year 3 months, from 0.42 to 2.33 years,
- male-extraction 1.22 years (almost 1 year 3 months), from 0.75 to 1.67 years,
- male-nonextraction 0.97 years (almost one year), from 0.25 to 1.5 years.

The present study was predominantly based on lateral cephalograms. Since all of the patients were treated by post-graduate students, the lateral cephalograms had to be obtained before the treatment started. This caused the average treatment time, as above, to be longer than the actual treatment time from the beginning of banding until stage 1. This extension to the true treatment time can be seen from three cases in the female-extraction group. One female patient had her initial radiograph obtained when she was 14 years, but the treatment began at 15.58 years. For the other two female patients, radiographs were obtained when they were 11.08 and 12.17 years, then the treatment was commenced when they were 13.92 and 13.25 years, respectively. One of the female-nonextraction group (radiograph was obtained when she was 12 years, but the treatment began at 13.17 years) had the lateral cephalogram obtained more than one year before the treatment started. The resultant changes in these females had included a longer time for growth than in others. This did not occur in the male groups. Although there was a longer gap between the time that lateral cephalometric radiographs were taken in the female-extraction group than in the female-nonextraction group, the average treatment time in the female-extraction group was shorter than the female-nonextraction group by one month. This is probably due to the average age of the female group being 13.67 years, and at this age females normally have passed their pubertal growth spurt. Therefore, correction of the Class II molar relationship to Class I by nonextraction treatment is generally more difficult than by extraction method because growth assistance may be limited.

In contrast, the male-nonextraction group had a shorter treatment time than the male-extraction group. This is because the average age for males was 13.47 years, and at this age the treatment time normally corresponds with the pubertal growth spurt. The nonextraction approach had growth to help Class II correction, while the extraction group were older and showed more crowding than the non-extraction patients. Consequently, the treatment time in the male-extraction group was longer than in male-nonextraction group. This is the same as the reports by Vig et al. (1990); Bishara et al. (1994); Bishara et al. (1995).

However, the treatment time in the present study can not be directly compared with other studies because the results from the present study were from the beginning until stage 1, not the entire treatment time from the beginning until bands off.

6.4 REFERENCE PLANES

The present study used superimposition of lateral cephalograms to obtain the best fit of the anterior wall of the anterior cranial base anatomy, internal cranial structures, and anterior wall of the sella turcica which is believed to be stable (Björk, 1960; Björk and Skieller, 1983). The present study used the x-y co-ordinate system. The x-axis was the sella-nasion minus 7° line and the y-axis was a line drawn from the landmark sella perpendicular to the x-axis. The reasons for using this reference plane were :

1. s and n points are located in the midsagittal plane and therefore are displaced a minimal degree by movement of the head. They are easily identified from the cephalograms.
2. Although the Frankfort horizontal plane is arguably more representative of the natural head position, it is difficult to locate the landmarks of porion and inferior rim of orbits. Furthermore, these two points are not midsagittal structures.
3. The sn line is steep compared to the Frankfort horizontal plane and is represented as though the patient's head is tilted forward and downward. This position is likely to cause incorrect identification of the soft tissue points. To compensate for the steepness of the sn line, 7 degrees is subtracted to provide a closer representation of the natural head orientation.

However, it is accepted that natural variation in cranial base anatomy will create inconsistency of the coordinate system between different patients.

4. It is acknowledged that the natural head position represents a standardised orientation of the head for the lateral cephalograms. This position is not used in the present study due to large staff turnover at the Radiology Department, Adelaide Dental Hospital. Different radiologists may introduce operator differences when instructing patients, which may result in discrepancies of the head position from the natural head posture.

6.5 TRACING AND DIGITIZING OF RADIOGRAPHS

There were errors from tracing and digitizing of the radiographs that were shown from an error study and double determination (chapter 5.1). The direct digitization of the radiographs is the most reproducible method, particularly for angular measurements, as compared with the hand measurement and digitization from the tracing methods. However, the linear measurement that requires the construction of points e.g. condylion, gonion, etc. is still more easily achieved by tracing the radiographs before digitizing (Sandler, 1988).

The mandibular plane angle (mdp/sn), posterior face height (pfh), and the ratio of lower anterior face height to total anterior face height (lafh/tafh) showed significant differences at $p<0.05$.

The major problems involved with tracing radiographs in the present study were :

1. locating the landmarks on the smooth curve e.g. superior labial sulcus (sls), soft tissue pogonion (pos), pogonion (pog). These landmarks showed significant differences along the vertical plane (y-axis) between the first and second determinations which agrees with Houston et al. (1986) who conclude that errors which arose in tracing radiographs highlighted the difficulties of identification of landmarks.

2. the tracing of the molar teeth positions. This was because :

   a. the molar teeth were bilateral structures;

   b. at stage 1, the molars were banded which made it more difficult to determine the landmark accurately because the bands were radiopaque and obscured the molar landmarks;

   c. the images of landmarks of the molar teeth on the lateral cephalograms were poorly resolved.

There were large errors in the variables that were involved with the molar positions and angulations. This uncertainty produced a slightly high error and less reliability in the variables that were involved with Downs occlusal plane in the present study.

Nasolabial angle and labiomental angle were also associated with large measurement errors due to the low accuracy in identifying the landmarks of the superior labial sulcus (sls) and soft tissue pogonion (pos). This problem also has been reported by Looi and Mills (1986).

6.6 DIFFERENCES BETWEEN GENDERS

Some studies have combined male and female samples together because of their small sample size e.g. Barton (1973); Edler (1977); Ball and Hunt (1991), etc., but others that have reasonable samples of each gender usually separate the gender e.g. Bishara (1994); Parker et al. (1995); the Michigan longitudinal growth study (Riolo et al., 1974); the Bhatia and Leighton longitudinal growth study (1993). This is because males and females have different craniofacial skeletons and soft tissue sizes, since males are generally larger than females. This result is the same as the present study in that males and females showed statistically significant differences in their facial dimension from the pre-treatment until stage 1. In addition, the treatment changes were not the same.

The male patients in the present study showed deeper overbite than the female patients because of their larger tooth size, which is the same as the studies of Parker et al. (1995); Bishara et al. (1995), while the Bhatia and Leighton longitudinal growth study (1993) showed no difference in overbite between genders.

From the pre-treatment radiographs, the lower incisor inclination to mandibular plane in females showed statistical significance for being more proclined than in males which is opposite to Sinclair and Little (1985); the Michigan longitudinal growth study; the Bhatia and Leighton longitudinal growth study because :

1. different malocclusions of samples in each study. The present study used only Class II division 1 malocclusion patients while Sinclair and Little (1985); the Michigan longitudinal growth study use Class I normal occlusion samples, and the Bhatia and Leighton longitudinal growth study uses all Class I normal, Class I crowding, Class II division 1, Class II division 2, and Class III occlusions mixed together in their samples.
2. different reference landmarks. The present study used the line that joined from gonion to gnathion as a mandibular reference plane, while the Bhatia and Leighton longitudinal growth study uses the line that joins from menton to gonion as a mandibular reference plane.

6.7 DIFFERENCES BETWEEN EXTRACTION AND NONEXTRACTION IN EACH GENDER

6.7.1 Male-extraction and male-nonextraction

6.7.1.1 pre-treatment

The mandibular plane angle and gonial angle were relatively steeper and larger in the male-extraction group than in the male-nonextraction group. This corresponds with the posterior face height and the ratio of posterior face height to total anterior face height which was higher in the male-nonextraction group, but there was no statistically significant difference between them. This is probably due to the extraction or nonextraction decision being made to avoid opening the high mandibular plane further, combined with greater crowding in these patients.

The upper incisor angulation relative to the cranial base and maxillary plane in the male-extraction group was significantly different at $p<0.05$ from the male-nonextraction group. Conversely, the lower incisor angulation relative to mandibular plane in the male-nonextraction group was more proclined than for the male-extraction group. This is the same as Bishara et al. (1994) who compared the craniofacial skeletal change between normal Class I samples with extraction and nonextraction Class II division 1 samples.

The nasolabial angle in the male-extraction group was more obtuse than the male-nonextraction group, which was surprising, since the upper incisor angulation in the male-extraction group was more proclined than in the male-nonextraction group and an obtuse nasolabial angle would seem to favour a nonextraction treatment. This is due to a number of factors. First, the male-extraction group had more long-faced patients than the male-nonextraction group. Secondly, the male-nonextraction group had a better skeletal pattern than the male-extraction group, which was seen from their smaller mandibular and maxillary length difference (co-gn minus co-a) of 21.7 mm, compared to the male-extraction groups 23.6 mm. Cadman (1975) indicates that one of the criteria to choose nonextraction treatment is good skeletal pattern.

6.7.1.2 at stage 1

The upper and lower incisors were more retroclined in the male-extraction than in the male-nonextraction group, corresponding with the interincisal angle which was larger in the extraction group because the extraction approach has space to reduce the proclination of the incisors. Correction of Class II relationships by nonextraction treatment proclined the lower incisors further. This finding is the same as Edler (1977); Meistrell et al. (1986); Bishara et al. (1995) but opposite to Thompson (1974) who reports the lower incisors do not change. However, these studies compared the pre-treatment with the final result.

The nasolabial angle was still larger in the male-extraction group than the male-nonextraction group, as in the pre-treatment stage.

6.7.1.3 changes

The sna was reduced by an average of 0.8° from the present study which is close to the results of Meistrell et al. (1986) who report the reduction of this angle by 0.74° from the pre-treatment until final stage. This means that the Begg appliance has a restriction effect on growth of the maxilla which agrees with the findings of Pridimore (1969); Cohen (1983); Haw-cited by Parker (1969).

The extraction treatment resulted in more retraction and retroclination of the upper incisors than the nonextraction treatment (Bishara et al., 1993) which is the same as the result from the present study. In the present study, the upper lip was retracted more in large overjet patients, and more posterior movement of the upper lip occurred in the extraction group than the nonextraction group which is the same as the conclusion of Looi and Mills (1986) who compared the upper lip retraction in Begg extraction treated patients with Andresen nonextraction treated patients.

The greater the retroclination of the upper incisor from the pre-treatment angulation results in the larger change of the distance from the upper incisor to maxillary plane and the greater change of the steepness of Downs occlusal plane. The male-extraction group showed more retroclination of the upper incisor angulation than the male-nonextraction group. Consequently, the change from upper incisal edge to maxillary plane and the change of the opening of Downs occlusal plane was greater in the male-extraction group than in the male-nonextraction group.

Lower incisor angulation relative to mandibular plane was proclined in both groups, and the degree of proclination was significantly larger in the nonextraction group than the extraction group. These findings agree with Edler (1977); Bijlstra (1969) who both use the Begg technique in their studies, and Bishara et al. (1994) who study the Edgewise technique. However, this contrasts with the findings of Barton (1973); Thompson (1974); Sim and Springate (1995) who report that the lower incisors are retroclined in the extraction group. However, the present study only compared from pre-treatment to stage 1, while other studies compare pre-treatment and the final result. The extraction cases in the Begg technique may need horizontal elastics during stage 2 which may retract the lower incisor such that the final lower incisor position may be more retroclined and/or more retruded than the result of the present study. The nonextraction cases in the Begg technique do not have stage 2, and usually use only Class II elastics, so the lower incisor should not have less angulation than at the end of stage 1 except in the cases that use labial auxiliary root torque.

Lo and Hunter (1982) report that the nasolabial angle increases by an average of 1.63° in their orthodontic treated group as do Farrer (1984); Looi and Mills (1986); Talass et al. (1987); Finnöy et al. (1987). The results of the present study were the same as other studies and the changes were similar in both extraction and nonextraction groups with an average increase of 2.1°. From normal growth, the nasolabial angle tends to reduce (Bhatia and Leighton, 1993) which is in contrast to Lo and Hunter (1982) who think that this angle does not change with growth.

The upper lip position closely relates to the position of the upper incisors (Ricketts, 1960; Bloom, 1961; Rudee, 1964; Wisth, 1974; Jacobs, 1978; Talass et al., 1987; Drobocky and Smith, 1989; Bishara et al., 1993; Bishara et al., 1995). The present study also showed that the upper lip moved further backward following the retroclination of the upper incisors in the extraction group than occurred in the nonextraction group, while Salzmann (1964) mentions that upper lip retraction is not always related to tooth movement but depends upon muscle size and tonicity.

There was more change in the backward position and downward position of b-point in the male-extraction group than in the male-nonextraction group. This is probably due to the high mandibular plane angle which is likely to be treated by extraction treatment and the growth direction of these patients which would likely be a backward rotation of the mandible (Björk, 1955).

6.7.2 Female-extraction and female-nonextraction

6.7.2.1 pre-treatment

The lower incisor angulation relative to the mandibular plane in the female-extraction group was significantly more proclined than in the female-nonextraction group, which was the same as the female patients in the study of Bishara et al. (1994). However, they found no significant difference in their study. This is possibly because of more bimaxillary protrusion and more tooth size arch length discrepancy in the female-extraction group than the female-nonextraction group.

The mandibular length (the distance from condylion to gnathion, co-gn) in the female-extraction group was shorter than the female-nonextraction group because of the greater skeletal discrepancies. Meistrell et al. (1986) indicate that one of the important criteria for choosing nonextraction treatment for each patient in the Begg technique is that the patient must have a good skeletal pattern which means the malocclusion is only from dentoalveolar discrepancies.

6.7.2.2 at stage 1

The mandibular length (co-gn) was still significantly shorter in the female-extraction group than in the female-nonextraction group because the average age of females was 13.67 years. Thus, it can be assumed that almost all of them would have passed their pubertal growth spurt already and did not have a lot of growth left during the treatment period.

6.7.2.3 changes

The lower incisor angulation relative to the mandibular plane in the female-extraction group showed less change in the proclined direction than in the female-nonextraction group, which agrees with Bishara et al. (1995). This is due to the treatment to correct the dental relationship from Class II to Class I in Begg stage 1. Normally, the lower incisors do procline because of Class II treatment mechanics. This is the same as the reports by Edler (1977); Bijlstra (1969); Williams (1977).

The ratio of posterior to total anterior face height in the female-nonextraction group reduced significantly more than in the female-extraction group. This corresponded with the opening of the mandibular plane angle that was larger in the female-nonextraction group. The results from the present study are quite similar to Chua et al. (1993) who use the ratio of lower anterior face height to total anterior face height instead of the ratio of posterior to total anterior face height.

The upper lip follows the change of underlying dental and skeletal supports (King, 1960; Ricketts, 1960; Bloom, 1961; Rudee, 1964; Wisth, 1974; Talass et al., 1987; Drobocky and Smith, 1989). In the present study, the nasolabial angle was opened more in the female-extraction group than in the female-nonextraction group like in the male group because the retraction of the upper incisors was greater in the extraction group than in the nonextraction group in both genders.

6.8 INTERLABIAL GAP

The male-extraction group in the present study showed significant reduction of the interlabial gap because the upper incisor was retroclined, thus causing the upper lip to move backward following the upper incisors and the upper lip in males still grows after 14 years of age (Nanda et al., 1995). Farrer (1984) reports that the Begg treatment technique results in reduction of the interlabial gap as well, but in contrast to Jacobs (1978) who studies Edgewise technique results and finds no correlation between maxillary incisor retraction with the vertical closure of the interlabial gap.

The interlabial gap slightly increased in both male-nonextraction and female-nonextraction, but this did not show statistically significant differences at $p<0.05$. The slight increase in the interlabial gap in these two groups probably came from a combination of many factors : less retroclination of upper incisors, more proclination of lower incisors, bracket thickness, and opening of the mandibular plane angle that was greater in the male-nonextraction group. The mandibular rotation is a significant variable to predict the upper and lower lips response from orthodontic treatment (Rains and Nanda, 1982). However, the interlabial gap may vary due to dependence upon whether the patient is instructed to close the lips together or let the lips relax when radiographs were taken. The relaxed lip position when taking the radiographs helps to reduce the variability in lip posture and to increase the reproducibility of soft tissue measurements (Burstone, 1967).

6.9 THE MANDIBULAR PLANE ANGLE

The steepness of the mandibular plane reduces with growth (Williams, 1968; Riolo et al., 1974; Bishara and Jakobsen, 1985; Sinclair and Little, 1985; Bhatia and Leighton, 1993). Normally, orthodontic treatment tends to increase the vertical dimension of the face (Stöckli and Teuscher, 1994) because of the extrusion of the posterior teeth during the treatment which causes the mandible to rotate downward and backward, opening the mandibular plane angle. This would explain the increase of the lower anterior face height (Riedel, 1960; Rocke, 1964; Haw-cited by Parker, 1969; Barton, 1973; Williams, 1968; Farrer, 1984; Ball and Hunt, 1991). These reports are the same as the present study that showed an average increase of 1.8° in males and 2.0° in females of the mandibular plane angle. In contrast, Meistrell et al. (1986) report that the mandibular plane is reduced by an average of 0.08° in Begg treatment technique from pre-treatment until the final stage except for their Class II subdivision patients who show an increase of 1.2°.

The vertical eruption of the lower molars by an average of 2.8 mm from the present study compared with normal growth of 1.6 mm from the Michigan longitudinal growth study and 1.0 mm from the Bhatia and Leighton longitudinal growth study in males, and by an average of 2.1 mm from the present study compared with normal growth of 0.9 mm from the Michigan longitudinal growth study and 0.8 mm from the Bhatia and Leighton longitudinal growth study in females. The other studies in Begg technique find some extrusion of the lower molars as well e.g. Rocke (1964) reports an extrusion of the lower molars of 3.1 mm from pre-treatment until stage 2, and 3.6 mm from pre-treatment until finishing, while Barton (1973) reports 2.3 mm and Miestrell et al. (1986) report 2.6 mm from pre-treatment until finishing. Conversely, there was slight intrusion of the upper molars compared to average growth. However, the landmarks of the molars in the present study were not clear on the lateral cephalograms.

The mandibular plane on average from the present study was opened in every treatment group (male-extraction, male-nonextraction, female-extraction, and female-nonextraction), but none of these groups showed statistically significant differences in the mandibular plane opening at $p<0.05$.

Patients in the male-nonextraction group showed a flatter mandibular plane angle than in the male-extraction group resulting in a higher percentage of short-faced patients in the nonextraction group than in the extraction group. The male-nonextraction group in the present study showed more opening of the mandibular plane angle than the male-extraction group. Therefore, it is suggested that during Begg treatment stage 1 in the present study, the mandibular plane angle was intentionally opened in these male short-faced patients as a treatment goal.

The female-nonextraction group showed more opening of the mandibular plane angle than the female-extraction, male-extraction, and male-nonextraction groups. This is probably because this group had the longest treatment time. The average treatment time for the female-nonextraction group (1.26 years) was longer than the female-extraction group (1.17 years), male-extraction group (1.22 years), and male-nonextraction (0.97 years) groups. This agrees with the pilot study of Vig et al. (1990). However, the molar positions and the mandibular plane angle showed less reliability than the other variables in the present study which is seen from the error study (chapter 5.1).

6.10 THE DOWNS OCCLUSAL PLANE ANGLE

The Downs occlusal plane is very sensitive and closely relates to both the upper and lower incisors, and the upper and lower molar positions. The increase in the steepness of Downs occlusal plane may come from the intrusion of the upper molars, extrusion of the lower molars, extrusion of the upper incisors, intrusion of the lower incisors, or any combination of these events.

During stage 1 of treatment, there was a slight intrusion of the upper molars, extrusion of the lower molars, retroclination of the upper incisors, and intrusion and proclination of the lower incisors. These effects act to correct the dental Class II relationships by holding the upper molars in the same vertical position while allowing lower molars to erupt upward and forward, and reducing the overjet/overbite by intrusion of the lower incisors and changing the incisor angulation. This caused the opening of Downs occlusal plane to become about twice the pre-treatment angulation during bite opening in stage 1.

The Downs occlusal plane was opened in every treatment group, which is opposite to the normal expected growth. The Downs occlusal plane relative to cranial base (sn) tended to reduce when the age increased (Riolo et al., 1974). This means that the opening of Downs occlusal plane was the effect from the Begg treatment technique during stage 1. Williams (1968) has reported that the occlusal plane and mandibular plane steepen only during the treatment and they tend to flatten post-treatment. However, the landmarks for the molar positions were difficult to ascertain from the lateral cephalograms, thus causing their positions to be determined with questionable accuracy.

6.11 RESULTS OF CORRELATION ANALYSIS

Male-nonextraction and female-nonextraction groups showed similar correlations (r = -0.66 and -0.65 respectively) in the change of variable 29, distance from lower incisor to mandibular plane (l1-mdp), to the facial pattern. The change of this distance was larger in long-faced patients than in short-faced patients in male-nonextraction and female-nonextraction groups. This is because normally this distance at the pre-treatment stage was greater in long-faced patients than short-faced patients. The treatment caused proclination of the lower incisors, and the larger the initial distance, the greater the change which occurred (Diagram 9) for a given incisor angulation.

Diagram 9 Perpendicular distance of lower incisor to mandibular plane changes in different face types

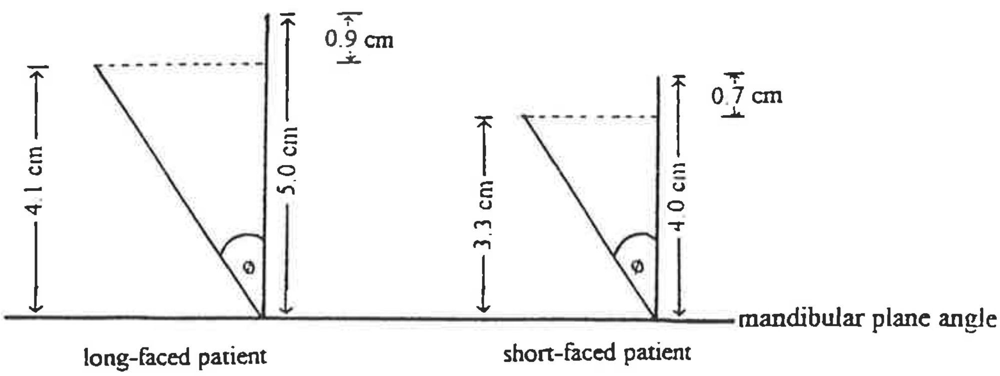


Diagram 9 illustrates the change of the perpendicular distance from lower incisor edge to mandibular plane after proclination has occurred. At the pre-treatment stage, the average of this distance was 5.0 cm in long-faced patients and 4.0 cm in short-faced patients. At stage 1, the lower incisors had proclined $\theta°$, resulting in this distance becoming 4.1 cm in long-faced patients and 3.3 cm in short-faced patients, so long-faced patients displayed a greater change of 0.9 cm compared to the short-faced patients change of 0.7 cm.

The change in variable 7, the steepness of the mandibular plane relative to cranial base (mdp/sn), showed a significant negative correlation (r = -0.65) to the face type only in the male-extraction group with all other groups showing no significant correlation. This means that long-faced patients showed more opening of the mandibular plane angle during Begg treatment stage 1 than the average-faced and short-faced patients. This effect could come from a combination of many factors e.g. :

1. The long-faced patients with steep mandibular plane angles were expected to have a downward and backward rotation of the mandible, while the short-faced patients with flat mandibular plane angles were expected to have an upward and forward rotation of the mandible from the normal direction of growth.
2. All of the orthodontic treatment techniques normally cause an opening of the mandibular plane.

The change in variable 25, posterior face height (pfh), showed a positive correlation (r = 0.53) to the facial pattern. The short-faced patients increased more in their posterior face height (sella to gonion, s-go) than long-faced patients during the treatment period because of individual growth patterns. Normally, the posterior face height increases more in short-faced patients than in long-faced patients. In addition, the mandibular rotation direction in short-faced patients tends to rotate upward and forward while long-faced patients tend to rotate downward and backward.

The change of the ratio of posterior face height to total anterior face height (pfh/tafh) showed a significant negative correlation (r = -0.44) in the female-nonextraction group. This means that short-faced patients displayed a greater increase of this ratio than long-faced patients which was opposite to the direction of normal expected growth because the treatment mechanic for short-faced patients with flat mandibular planes is to try to open the mandibular plane and increase the lower anterior face height. This is opposite to that in long-faced patients where avoidance of any opening of the mandibular plane is usually desired.

The nasolabial angle opened more in long-faced patients than short-faced patients. This is associated with both growth and treatment effect. Logically, long-faced patient features are upturned nose, obtuse nasolabial angle, thin and short upper lip, and reduced chin prominence. These features are the opposite in short-faced patients, who normally show about ninety degrees or an acute nasolabial angle, thick upper lip, and strong chin. The treatment mechanics to reduce the overjet normally aim to retract the upper incisors, which causes the upper lip to move back more easily in long-faced patients and shows more change in the nasolabial angle. However, the nasolabial angle variable showed a high percentage error variance from the double determination.

The change of variable 6, maxillary plane to cranial base (mxp/sn), showed negative correlation (r = -0.44) with the facial pattern. This means long-faced patients tended to have more opening of this angle than short-faced patients. This result is likely to be caused by the growth direction of each facial pattern. According to Sassouni (1960), long-faced patients showed four diverging reference planes (optic, maxillary, occlusal, and mandibular plane) while short-faced patients showed paralleling of these four reference planes.

The results from the present study showed that the orthodontic treatment response following Begg treatment technique stage 1 depended upon face type. By contrast, Bishara et al. (1994) have studied the post-treatment changes in different face types, and conclude that the stability following orthodontic treatment is not dependent upon the face type. However, their study does not compare face type and treatment changes through the period of active period and retention.

6.12 COMPARISON OF THE RESULTS FROM THE PRESENT STUDY WITH PUBLISHED LONGITUDINAL GROWTH STUDIES

It is difficult to separate those changes that are caused by treatment only from those that are caused by growth only, because individuals had different directions, rates, and amounts of growth during the duration of the present study.

The Begg treatment stage 1 has a restriction effect on the maxilla. This was indicated by the sna angle that showed a slight reduction and the maxillary length (co-a) that showed a smaller increase compared with the data from the Bhatia and Leighton longitudinal growth study. The result from the present study was similar to the studies of Haw-cited by Parker (1969) who reports that there is a reduction of a-point from the Begg treatment technique, Pridimore (1969) who says that the angle anb reduces by an average of 3.07° from his 21 Class II division 1 treated patients, due to the backward movement of a-point, and Meistrell et al. (1986) mention that the Begg appliance has a restriction effect on maxillary growth caused by reduction of the sna angle.

The treatment had an effect on the maxillary dentition as indicated by the large reduction in the upper incisor angulation compared with the data from both longitudinal growth studies, and in agreement with all the studies in the Begg technique.

The perpendicular distance from the lower incisal edge to the mandibular plane increases from normal growth, but showed a decrease in this distance from the present study. This means that the Begg appliance intrudes and proclines the lower incisors during stage 1.

The vertical position of the upper first molar showed slightly less vertical development than the data from both longitudinal growth studies. There is normal vertical development of the maxillary molars by an average 1 mm in males and 0.7 mm in females (from the Bhatia and Leighton longitudinal growth study). The present study showed a vertical development on average of 0.9 mm in males and 0.4 mm in females, which was the same as reports of Barton (1973) who reports that there is vertical development of the upper molars by an average 0.69 mm, and Rocke (1964) who reports that the upper molar shows an average vertical development by average of 0.7 mm from pre-treatment until the end of stage 2 and 1.2 mm from pre-treatment until the finishing stage. However, the accuracy of the molar position variables was questionable because of the reasonably high measurement error associated with the molar landmarks.

The increases in the mandibular length (co-gn, ar-gn) of the present study during stage 1 was similar to both the average values of the longitudinal growth studies for males, but was smaller than the average values for females.

This is due to the patients in the present study having a wide age range from 10.5 to 16.0 years, so the average growth was calculated using some patients that may not have had any growth during the treatment period, and also that the nature of Class II malocclusion is mandibular deficiency.

There was a large effect on the mandibular dentition which comprised :
1. proclination of the lower incisors by an average of 5° in males and 4.5° in females, which was the same as the studies by Bijlstra (1969); Williams (1977); Edler (1977) but opposite to the Bhatia and Leighton longitudinal growth study that shows no change in males and a retroclination by -0.4° in females;
2. lower molar extrusion of 2.8 mm in males and 2.1 mm in females in the present study which was quite similar to many reports by Rocke (1964); Williams (1968); Barton (1973); O'Reilly (1979); Meistrell et al. (1986), while the average growth is 1.0 mm in males and 0.8 mm in females. Rocke (1964) reports that the vertical height change of the lower molars is 3.1 mm from beginning to stage 2 and 3.6 mm from pre-treatment to finishing.

The mandibular plane angle was increased by an average of 1.8° in males and 2.0° in females which seems to be as normally expected because orthodontic treatment tends to cause a mandibular plane opening during treatment, then it tends to return to its original orientation post-treatment (Williams, 1968).

The lower anterior face height from the present study was increased by an average of 5.1 mm in males and 3.4 mm in females. This increase was greater than that for normal expected growth from Bhatia and Leighton longitudinal growth study (1.6 mm in males and 0.8 mm in females) because of the effect which followed the downward and backward rotation of the mandible combined with growth. This result is similar to the treatment effect of functional appliances (McNamara et al., 1985; Nelson et al., 1993) and the reports of Stöckli and Teuscher (1994) who say that all treatments tend to increase the vertical dimension of the dentoalveolar height.

The interincisal angle from the present study showed a greater increase than average growth because normally, Begg technique stage 1 retroclines the upper incisors and sometimes proclines the lower incisors to reduce the overjet. However, after stage 3 of treatment, the upper incisor angulation will be closer to the ideal angulation.

The vertical position of the lower incisors shows an increase in the vertical dimension for normal growth but showed a decrease in the present study because of the proclination of the lower incisors combined with the intrusion effect of the appliance. This is the same as the reports from Williams (1968); Rocke (1964).

The Begg treatment technique is very effective in reducing the overjet and overbite. From the present study, the overbite reduced considerably by an average of 4.0 mm compared with average growth from the Bhatia and Leighton longitudinal growth study that shows no change.

The average of the ratio of posterior to total anterior face height was not changed in males and slightly decreased by an average of 0.01 in females by the treatment. That is the same as normal expected growth from 13 to 14 years in both of the longitudinal growth studies. According to Gebeck (1989); Merrifield (1989); Horn (1992), successful treatment is indicated by no change or an increase of the ratio of posterior face height to total anterior face height. This means that the Begg treatment technique stage 1 is a successful treatment in males and causes a slight decrease of this ratio in females.

CHAPTER 7 : CONCLUSIONS

1. The total sample was sufficient, but after division into groups for each face type, each group was rather small.
2. There were errors from the tracing and digitizing mainly in the variables that were involved with the mandibular plane, posterior face height, ratio of posterior to total anterior face height, molar position, occlusal plane, and nasolabial angle.
3. The changes from Begg technique found during stage 1 were :
    1. reduction of sna angle and restriction of maxillary growth;
    2. retroclination of upper incisors;
    3. slight intrusion of upper molars;
    4. intrusion of lower incisors;
    5. proclination of lower incisors;
    6. slight extrusion of the lower molars;
    7. opening Downs occlusal plane by downward and backward tipping.
4. Begg technique stage 1 effectively reduced the interlabial gap in the male-extraction group.
5. The null hypothesis that "treatment responses are independent of facial pattern" was rejected.

The treatment response during Begg stage 1 depended upon facial pattern in the following variables :

- In the male-nonextraction group :

    -the change of the distance from the lower incisors to mandibular plane in long-faced patients was greater than in short-faced patients.

- In the male-extraction group :

    -the change of the steepness of the mandibular plane angle in long-faced patients was larger than in short-faced patients;

    -the increase of posterior face height in short-faced patients was greater than in long-faced patients.

- In the female-nonextraction group :

    -the change of the distance from the lower incisors to the mandibular plane in long-faced patients was greater than in short-faced patients;

    -the opening of the nasolabial angle in long-faced patients was larger than in short-faced patients.

- In the female-extraction group :

    -the increase in the steepness of the maxillary plane to cranial base in long-faced patients was larger than in short-faced patients.

6. All of the aims of this study were achieved.
7. Further studies of the Begg technique during stage 2, stage 3, and post-treatment effect will be useful.

CHAPTER 8 : APPENDICES

8.1 APPENDIX 1
LANDMARK IDENTIFICATION

1. Sella, s. : The center of the pituitary fossa of the sphenoid bone. Determined by inspection.
2. X-axis, x : any point on horizontal reference plane (sn 7°).
3. Nasion origin, n-o. : The junction of the frontonasal suture at the most posterior point on the curve at the bridge of the nose (of the pretreatment cephalogram).
4. Nasion stage1, n-1. : The junction of the frontonasal suture at the most posterior point on the curve at the bridge of the nose (of the stage 1 cephalogram).
5. Soft tissue nasion, nas. : The deepest concavity between the nose and the forehead.
6. Pronasale, prn. : The most prominent point on the contour of the nose.
7. Columella point, cm. : The most anterior point on the columella of the nose.
8. Subnasale, sn. : The point where the maxillary lip and septum form a definite angle. If the depression is a gentle curve, subnasale was interpreted as the most concave point in this area as measured by a line angled 45 degrees from the nasal floor.
9. Superior labial sulcus, sls. : The deepest point on the upper lip as determined by a line drawn from subnasale inclined so that it forms a tangent with labrale superius.
10. Labrale superius, ls. : The most prominent point on the upper lip as measured from a perpendicula to the nasal floor.
11. Inferior aspect upper lip, iul. : A definition of this point could not be found in the literature, although it was commonly used. It could be defined as the most inferior point on the upper lip contour with relation to a horizontal plane of reference, for example sn 7°.
12. Superior aspect lower lip, sll. : A definition of this point could not be found in the literature, although it was commonly used. It could be defined as the most superior point on the lower lip contour with relation to a horizontal plane of reference, for example sn 7°.
13. Labrale inferius, li. : The most prominent point on the lower lip as determined by a perpendicular from nasal floor.
14. Inferior labial sulcus, ils. : The most concave point as measured by a line tangent to menton point (soft tissue) and labrale inferius.
15. Soft tissue pogonion, pos. : The most anterior point on the chin as determined from a perpendicular to nasal floor.
16. Soft tissue gnathion, gns. : The point on the chin contour at the intersection of a line through sella and gnathion.

17. Menton, me. : The most inferior point on the symphyseal outline.

18. Gnathion, gn. : The most anterior-inferior point on the contour of the bony chin symphysis. Determined by bisecting the angle formed by the mandibular plane and a line through pogonion and nasion.

19. Pogonion, pog. : The most anterior point on the contour of the bony chin. Determined by a tangent through Nasion.

20. B point, b. : The point most posterior to a line from infradentale to pogonion on the anterior surface of the symphseal outline of the mandible.

21. Infradentale, id. : The anterior superior point on the mandible (alveolar process) at its labial contact with the mandiblular central incisor.

22. Lower incisor apex, lia. : The root tip of the mandibular central incisor. (This point is related to the central incisor with the most anterior crown position).

23. Incisal edge inferior, iei. : The incisal tip of the mandibular central incisor.

24. Incisal edge superior, ies. : The incisal tip of the maxillary central incisor.

25. Anterior Downs Point, adp. : The midpoint of the line connecting landmarks 23 and 24 (iei and ies) This represents the anterior point through which Downs Occlusal Plane passes.

26. Supradentale, sd. : The most anterior inferior point on the maxilla (alveolar process) at its labial contact with the maxillary central incisor.

27. A Point (Subspinale), a. : The most posterior point on the maxilla between the anterior nasal spine and supradentale.

28. Upper incisor apex, uia. : The root tip of the maxillary central incisor. In cases where the root is not yet completed, the midpoint of the growing root tip is marked. (In relation to the central incisor with the most anterior crown position).

29. Anterior nasal spine, ans. : The tip of the median, sharp bony process of the maxilla at the lower margin of the anterior nasal opening.

30. Posterior nasal spine, pns. : The most posterior point at the sagittal plane on the bony hard palate.

31. Upper molar mesial cusp tip, umt. : The mesial cusp tip of the maxillary first molar.

32. Upper molar distal cusp tip, udt. : The distal cusp tip of the maxillary first molar.

33. Upper molar furcation, ufur. : The root furcation of the maxillary first molar.

34. Upper molar furcation perpendicular to occlusal surface of molar, umf : The point on occlusal surface of upper first molar perpendicular to the line drawn from furcation.

35. Lower molar mesial cusp tip, lmt. : The mesial cusp tip of the mandibular first molar.

36. Posterior Downs Point, pdp. : The midpoint of the line connecting landmarks 34 and 35 (umt and lmt). This represents the posterior point through which Downs Occlusal Plane passes.

37. Lower molar distal cusp tip, ldt. : The distal cusp tip of the mandibular first molar.

38. Lower molar furcation, lfur. : The root furcation of the mandibular first molar.

39. Lower molar furcation perpendicular to occlusal surface of molar, lmf. : The point on occlusal surface of lower first molar perpendicular to the line drawn from furcation.

40. Gonion, go. : The midpoint of the angle of the mandible. Found by intersecting the angle formed by the mandibular plane and a plane through articulate posterior and along the portion of the mandibular ramus inferior to it.

41. Articulare, ar. : The point of intersection of the inferior cranial base surface and the averaged posterior surfaces of the mandibular condyles.

42. Condylion, co. : The most posterior superior point on the curvature of the average of the right and left outlines of the condylar head. Determined as the point of tangency to a perpendicular construction line to the anterior and posterior borders of the condylar head. The co point is located as the most superior axial point of the condyle head rather than as the most superior point on the condyle.

43. Porion, po. : The most superior point on the radiolucency of the external and internal auditory meati. It is located posterior to the mandibular condyle and posterior clivus.

44. Orbitale, or. : The most inferior point on the lower border of the bony orbit.

POINTS USED FOR PLOTTING PURPOSES ONLY

These points, together with sella (which defines the origin or (0,0)) define the x and y axes of the cartesian coordinate system.

The name is followed by the symbol used in the present study.

- x-align, x : any point on the x-axis (the sn7° line from pre-treatment radiograph) used to define the x-axis (horizontal reference plane) in conjunction with sella.
- y-align, y : any point on the y-axis (the perpendicular line with sn7° through sella from pre-treatment radiograph) used to define the y-axis.

8.2 APPENDIX 2
SUPERIMPOSITION TECHNIQUE

The technique used was that of Björk and Skieller (1983).
The procedure followed can be listed in stages:

1. Two Björk transparent plastic sheets, each with a thin black cross line oriented 7° to each other were fixed together with sticky tape. This was then mounted on the viewing screen with sticky tape.
2. The pre-treatment radiograph was examined and sella and nasion were identified and the points marked lightly on the film.
3. The pre-treatment radiograph was then secured with tape to the screen with the s point at the center of the cross line, and the 7° to the sn line lying on the x-axis.
4. Unitek tracing paper was then secured to the radiograph and the screen with tape. Nasion, sella, x-align, and y-align were transferred to the tracing paper.
5. All of the points for digitizing were then identified and marked.
6. Relevant information was marked on the tracing paper including the identification number, sex, age, and treatment (extraction or nonextraction).
7. The tracing paper was removed.
8. The post-treatment radiograph was then superimposed on the pre-treatment radiograph based on intracranial base structure (Björk and Skieller, 1983).
9. The pre-treatment sella, intersection of the cross, a point on the x-axis (x-align), and a point on the y-axis were then marked lightly on the stage1 film.
10. The pre-treatment film was removed from the screen.
11. The points for the reference axes and landmarks were then traced on tracing paper for stage 1 film.
12. Relevant information was marked on the tracing paper for example, the identification number, sex, age, and treatment (extraction or nonextraction).

8.3 APPENDIX 3

VARIABLE DESCRIPTIONS

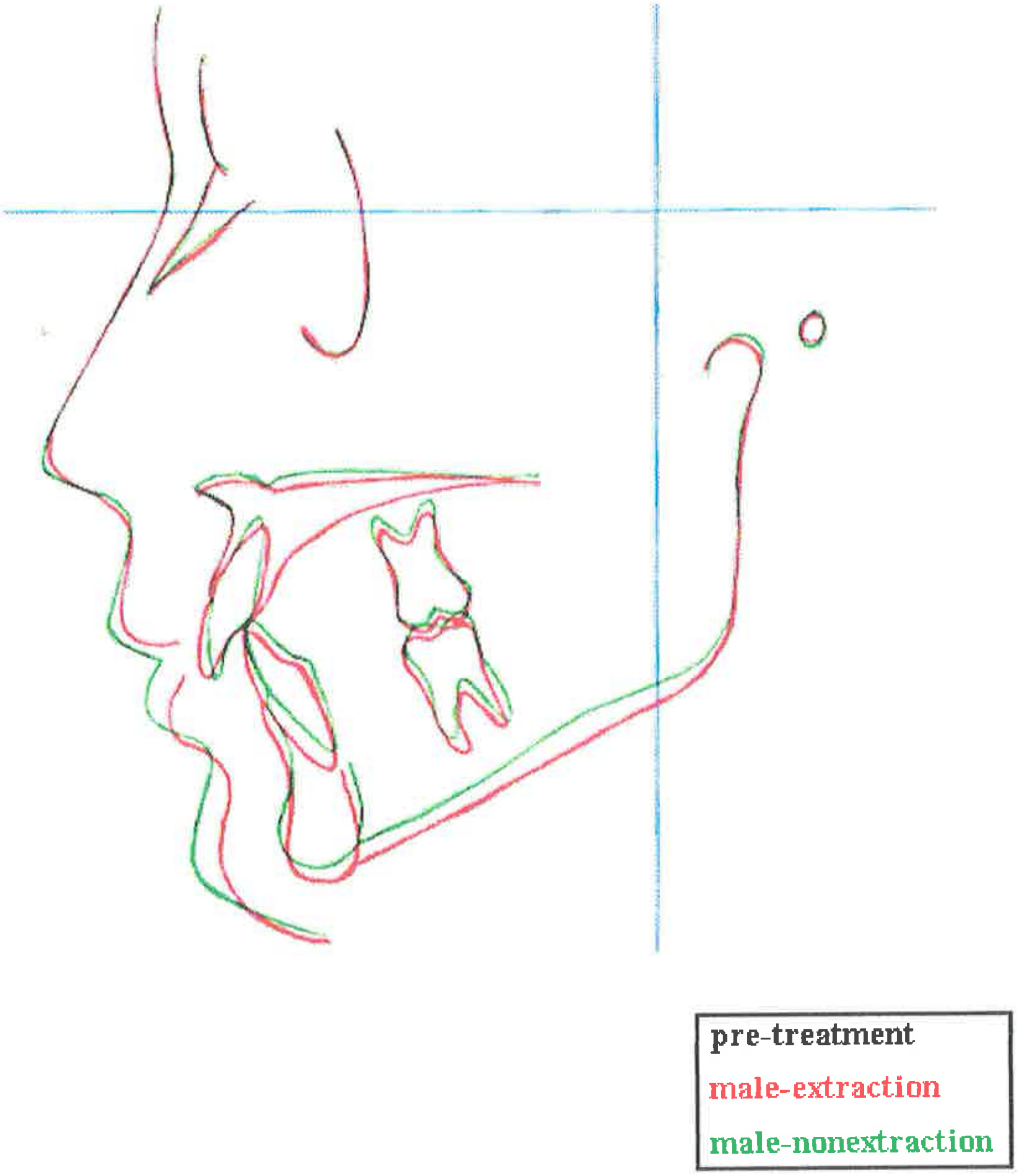
Table 29 Variable descriptions

variable no.	Variable	type	landmark no.	landmark name
1	sna	angular	1/4/27	s/n/a
2	snb	angular	1/4/20	s/n/b
3	sn7/dop	angular	1-2/36-25	sn7/pdp-adp
4	mxp/dop	angular	30-29/36-25	pns-ans/pdp-adp
5	mdp/dop	angular	18-40/36-25	gn-go/pdp-adp
6	mxp/sn	angular	30-29/4-1	pns-ans/n-s
7	mdp/sn	angular	18-40/4-1	gn-go/n-s
8	mxp/mdp	angular	30-29/40-18	pns-ans/go-gn
9	u1/sn7	angular	24-28/1-2	ies-uia/s-x
10	u1/mxp	angular	24-28/29-30	ies-uia/ans-pns
11	l1/sn7	angular	23-22/2-1	iei-lia/x-s
12	l1/mdp	angular	23-22/18-40	iei-lia/gn-go
13	ar/go/gn	angular	41/40/18	ar/go/gn
14	ii	angular	28-24/23-22	uia-ies/iei/lia
15	u6/sn7	angular	33-34/1-2	ufur-umf/s-x
16	u6/mxp	angular	33-34/29-30	ufur-umf/ans-pns
17	l6/sn7	angular	39-38/2-1	lmf-lfur/x-s
18	l6/mdp	angular	39-38/18-40	lmf-lfur/gn-go
19	ar-gn	linear	41-18	ar-gn
20	co-gn	linear	42-18	co-gn
21	co-a	linear	42-27	co-a
22	uafh	linear	29-4	ans-n
23	lafh	linear	29-17	ans-me
24	tafh	linear	4-17	n-me
25	pfh	linear	1-40	s-go
26	lafh/tafh	ratio	29-17/4-17	ans-me/n-me
27	pfh/afh	ratio	1-40/4-17	s-go/n-me
28	u1-mxp	angular	24/29-30	ies/ans-pns
29	l1-mdp	angular	23/18-40	iei/gn-go
30	u6-mxp	angular	31/29-30	umt/ans-pns
31	l6-mdp	angular	35/18-40	lmt/gn-go
32	prn-gns	linear	6-16	prn-gns
33	nasolab/a	angular	7/8/9	cm/sn/sls
34	labmen/a	angular	13/14/15	li/ils/pos
35	oj	linear	23-24	iei to ies along dop
36	ob	linear	23-24	iei to ies perpendicular to dop
37	ao/bo	linear	27-20	a to b along dop
38	bx	linear	20	b (x-axis)
39	by	linear	20	b (y-axis)
40	pog-x	linear	19	pog (x-axis)
41	pog-y	linear	19	pog (y-axis)
42	iul-x	linear	11	iul (x-axis)
43	iul-y	linear	11	iul (y-axis)
44	sll-x	linear	12	sll (x-axis)
45	sll-y	linear	12	sll (y-axis)

8.4 APPENDIX 4
COMPARISONS OF AVERAGE TRACINGS

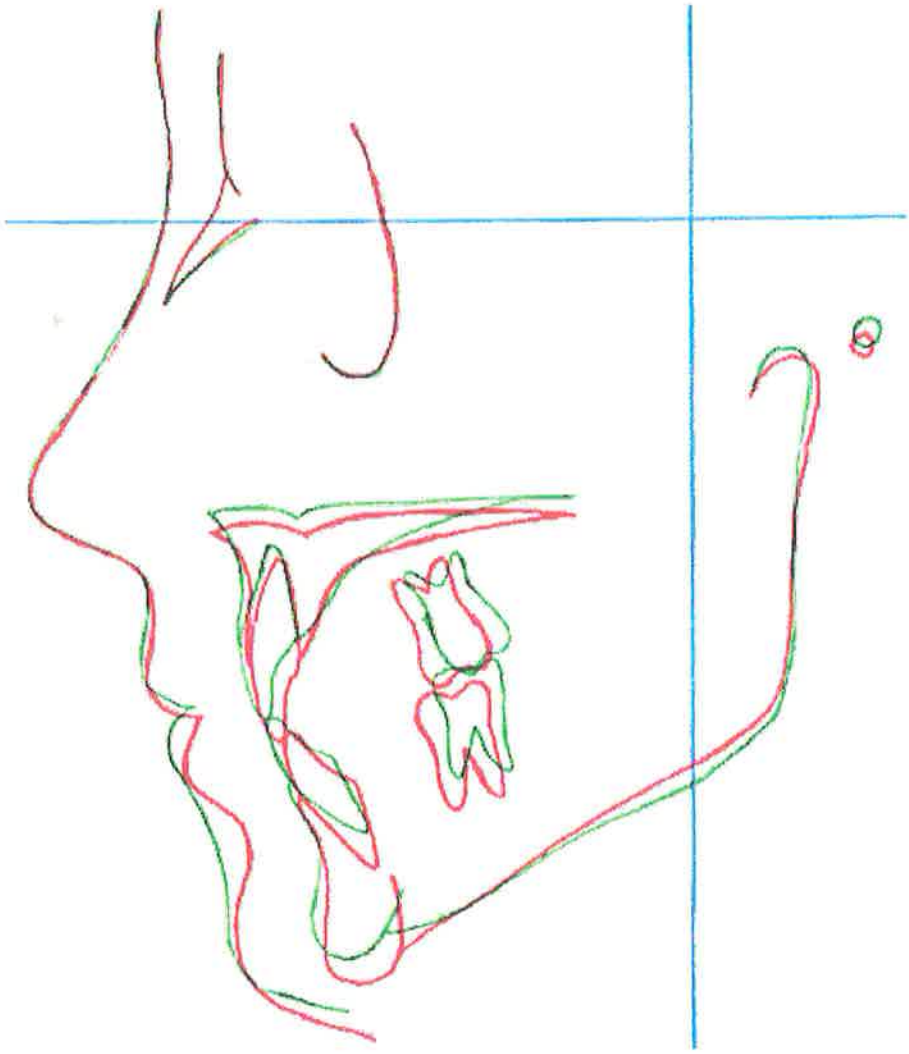
Appendix 8.4.1

Fig. 15 Comparison of average tracings of male-extraction and male-nonextraction patients at pre-treatment



Appendix 8.4.2

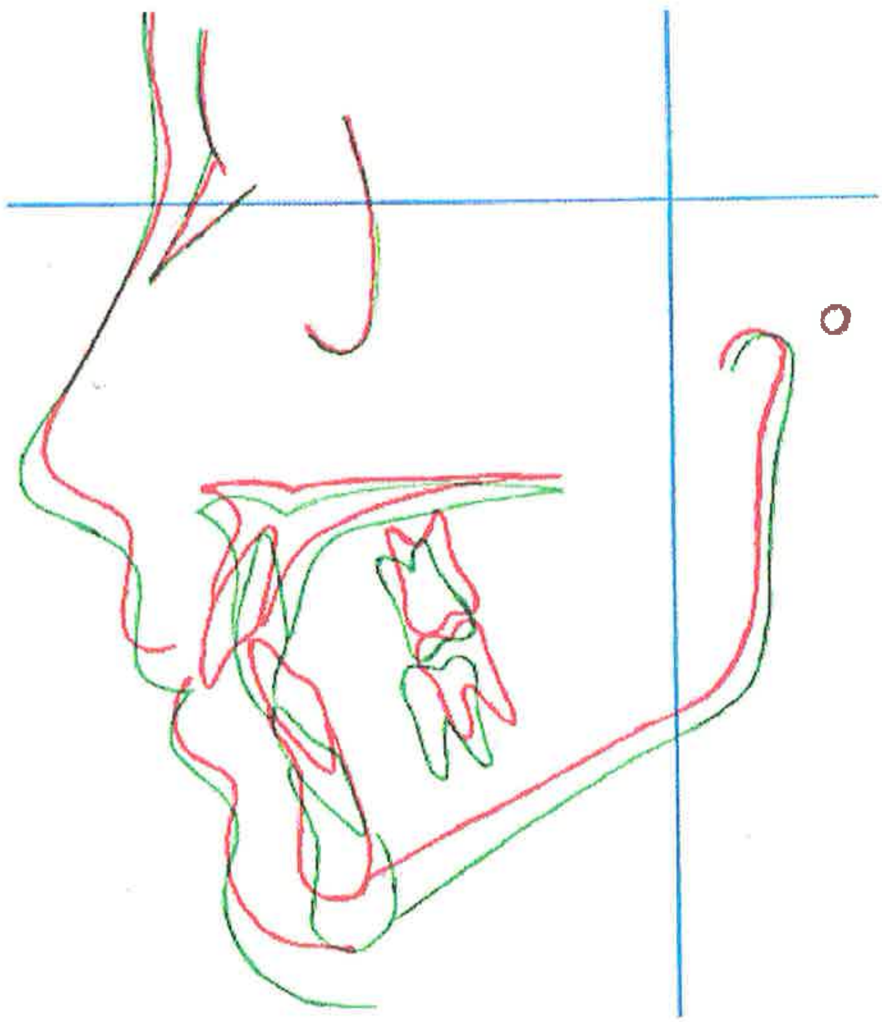
Fig. 16 Comparison of average tracings of male-extraction and male-nonextraction patients at stage 1



at stage 1
male-extraction
male-nonextraction

Appendix 8.4.3

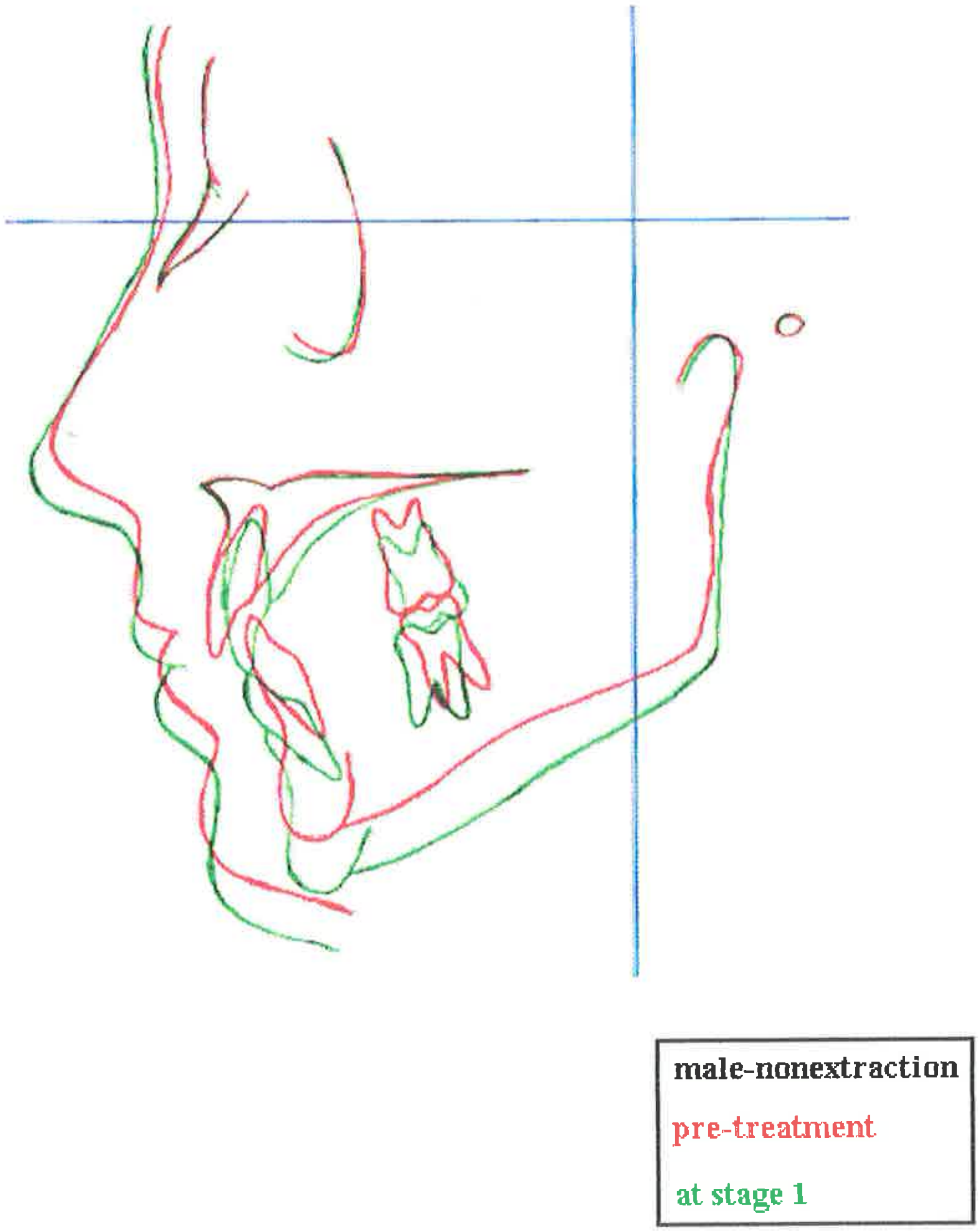
Fig. 17 Comparison of average tracings of male-extraction patients at pre-treatment and at stage 1



male-extraction
pre-treatment
at stage 1

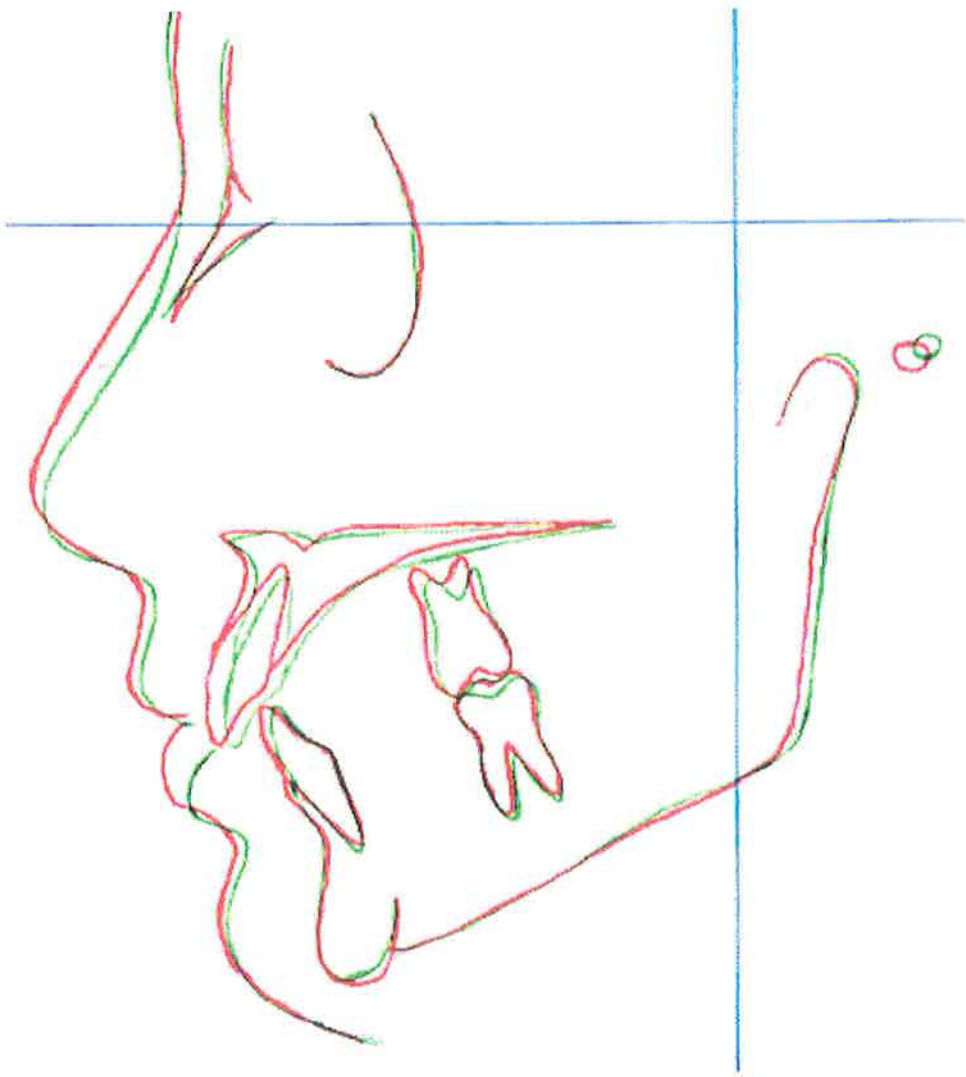
Appendix 8.4.4

Fig. 18 Comparison of average tracings of male-nonextraction patients at pre-treatment and at stage 1



Appendix 8.4.5

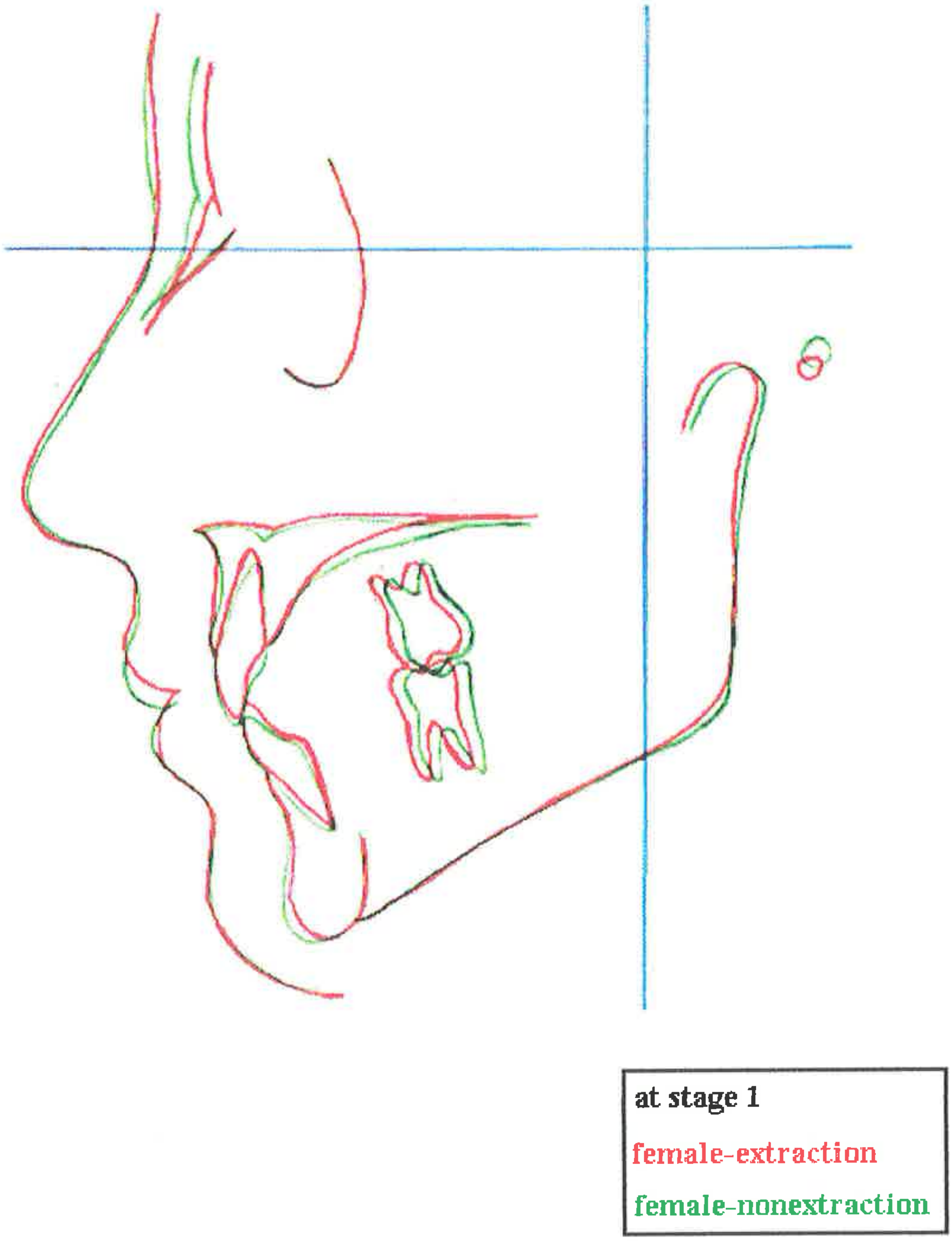
Fig. 19 Comparison of average tracings of female-extraction and female-nonextraction patients at pre-treatment



pre-treatment
female-extraction
female-nonextraction

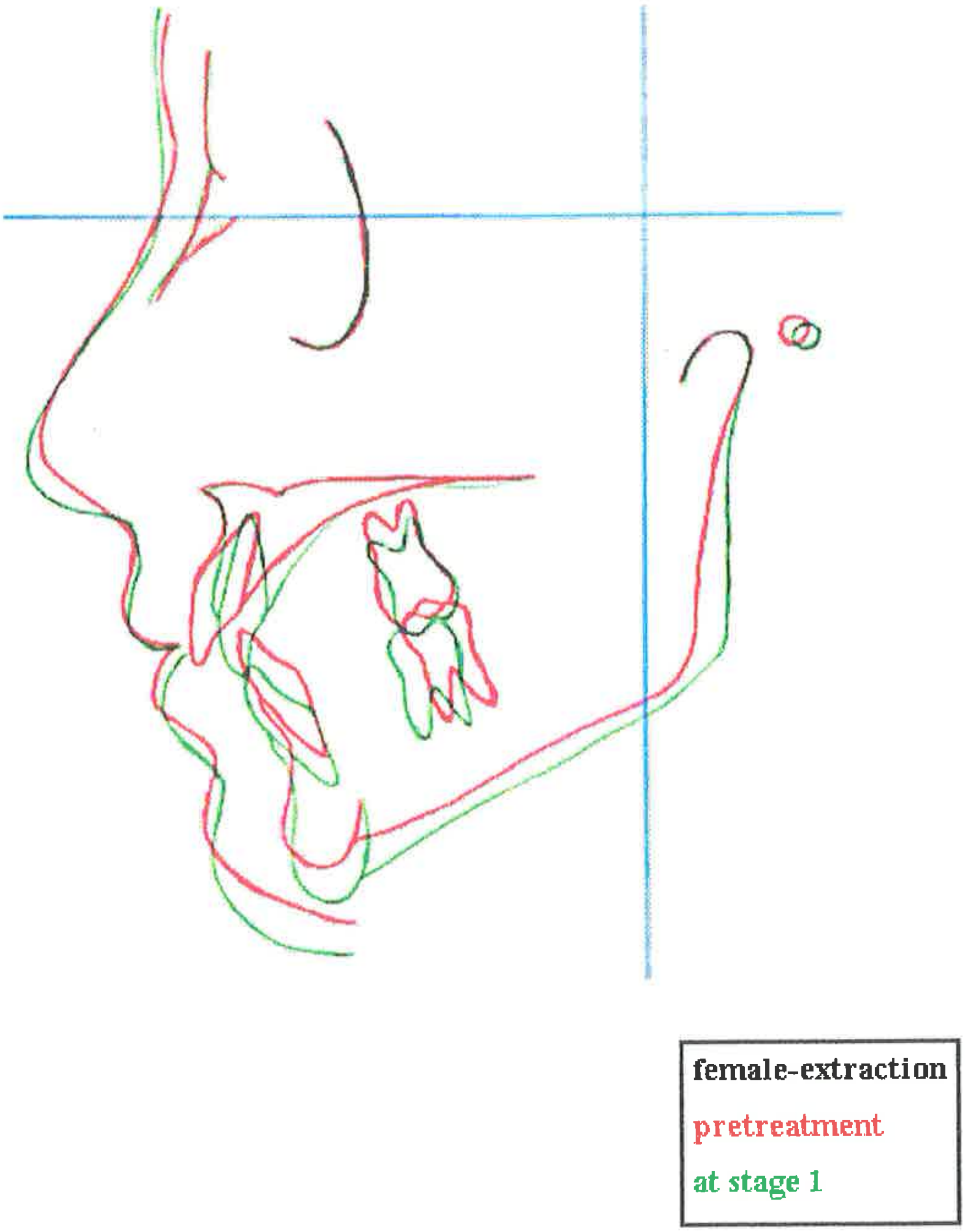
Appendix 8.4.6

Fig. 20 Comparison of average tracings of female-extraction and female-nonextraction patients at stage 1



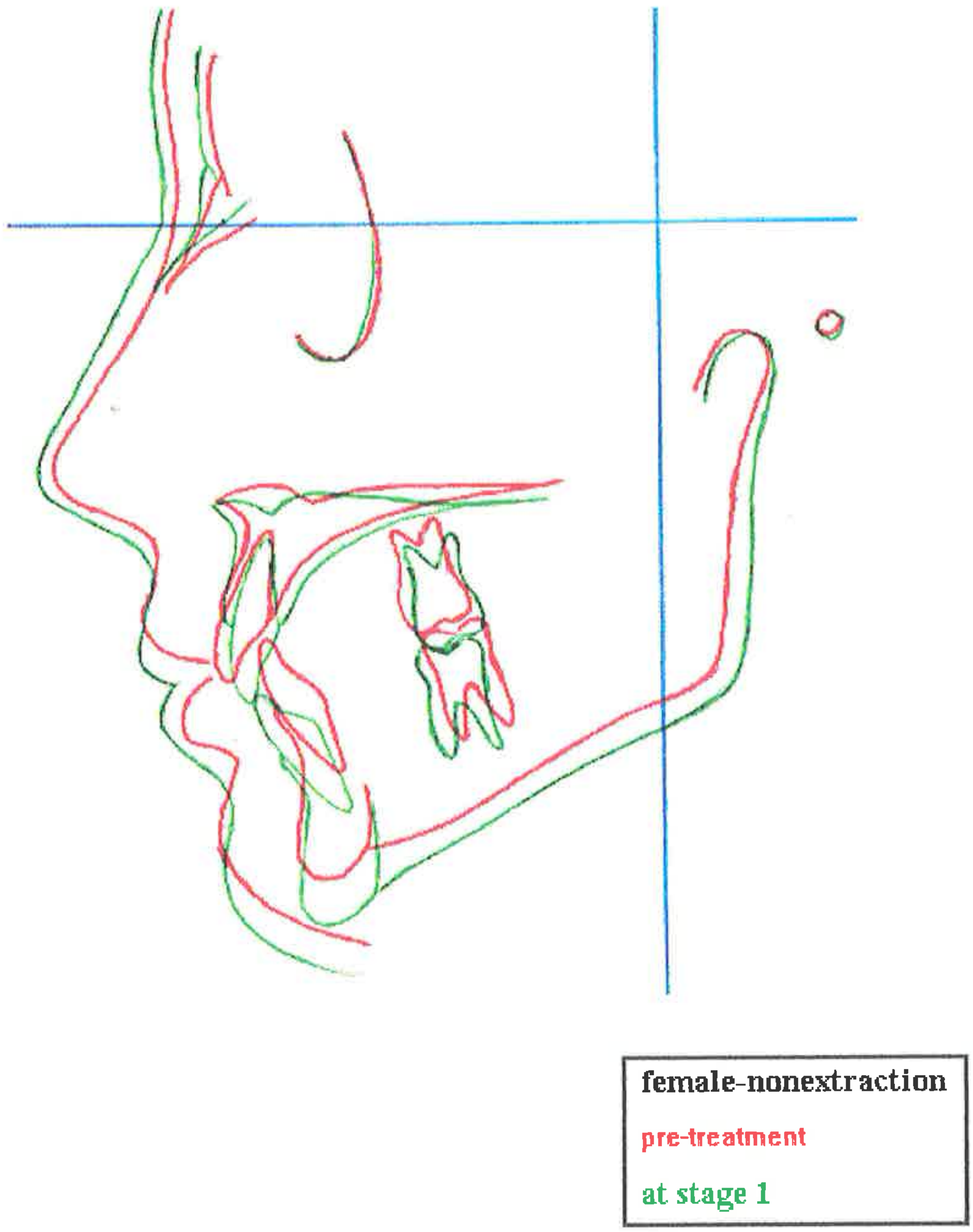
Appendix 8.4.7

Fig. 21 Comparison of average tracings of female-extraction patients at pre-treatment and at stage 1



Appendix 8.4.8

Fig. 22 Comparison of average tracings of female-nonextraction patients at pre-treatment and at stage 1



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