The Intraoral Inverted 'L' osteotomy for Mandibular Advancement

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SUMMARY

This study was undertaken to investigate the intraoral inverted 'L' osteotomy for mandibular advancement. The stability of the intraoral inverted 'L' osteotomy was assessed by cephalometric analysis over the short, medium and long term and this was compared to the stability of the bilateral sagittal split osteotomy and the extraoral inverted 'L' osteotomy. A second part of the study investigated the incidence of neurosensory disturbance following inverted 'L' osteotomy and comparedit to bilatteral sagittal split osteotomy.

The cephalometric study involved detailed analysis of 33 sets of cephalometric records from 5 retrospective and 28 prospective patients.

The 33 records were assigned to one of three groups.

Group I: **intraoral inverted 'L' osteotomies** (n = 14).

Group II: **bilateral sagittal split osteotomies** (n = 15).

Group III: **extraoral inverted 'L' osteotomies** in conjunction with **standard Le Fort I osteotomies** (n = 4).

Changes due to surgery and subsequent changes over time were assessed for a group of selected cephalometric variables.

The results of the study showed that mean relapse of point B in the horizontal was for Groups I and II was less than 21% with no statistically significant difference between the two groups. Individuals however showed marked

variation, with one individual in Group I relapsing more than 100% of the surgical advancement. Several patients demonstrated postsurgical anterior movement of B point and this could be attributed to anticlockwise rotation of the mandible. Group III exhibited a mean of 44% relapse of B point in the horizontal however this group were very dissimilar to the other groups both in terms of the pre existing deformity and the magnitude of the surgical shifts.

The most striking feature seen over the postoperative time periods was a loss of the gonial angles in Group I, this was reflected in changes in: the gonial angle, mandibular plane angle, ramal angle and posterior face height.

The hyoid bone moved forward with surgery in all groups and relapsed back only insignificant amounts in Groups I and II, however in Group III it moved back almost 50% of its original advancement. Tho only significant ($p<0.05$) changes seen in the vertical position of the hyoid bone were seen in Group III where the hyoid bone moved inferiorly a mean distance of 3.4 mm post surgically.

The neurosensory part of the study involved subjective and objective testing of 20 patients, 9 each from Groups I and II and 2 from group III. The distribution of the mental nerves were tested using light touch, pinprick and two point discrimination. Statistical analysis of the results of the two point discrimination showed that there was a statistically significant difference ($p<0.05$) between Group I and II with Group I having better two point discrimination. Thus there was a lower incidence of neurosensory disturbance with the intraoral inverted 'L' osteotomy.

The merino sheep was used as animal model for investigating the inverted 'L' osteotomy. One sheep was operated upon, under a general anaesthetic its mandible was advanced using the inverted 'L' osteotomy. The animal was sacrificed and the mandible removed and examined. The experiment showed that the sheep is a useful animal model for further evaluation. Further studies were not conducted because of insufficient research grant funds.

STATEMENT

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Dental Surgery. I declare that the text of this thesis has not been previously published or written by another person except where due reference is made. The findings are the result of my personal investigations. No part of this work has been previously submitted for a degree in any University.

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I

INTRODUCTION

CHAPTER 1

THE INTRAORAL INVERTED 'L' OSTEOTOMY FOR MANDIBULAR ADVANCEMENT

1.1 OVERVIEW

Mandibular deficiency is a common dentofacial deformity, particularly amongst populations of European origin, and it may cause aesthetic disharmony and functional limitations. Traditionally the bilateral sagittal split osteotomy has been the gold standard for correction of mandibular deficiency. This procedure has been associated with varying degrees of relapse and neurosensory defects. Hence the object of this study was to refine the intraoral inverted 'L' osteotomy and compare its stability and incidence of neurosensory disturbance to the bilateral sagittal split osteotomy.

The features and incidence of mandibular deficiency are discussed in Chapter 2, as are the main surgical techniques which have been described to correct mandibular deficiency. A history of the development of mandibular advancement osteotomies is included with particular emphasis on the bilateral sagittal split and the inverted 'L' osteotomies. The complications associated with these operations are reviewed, and the use of bone grafts with the inverted 'L' osteotomy is also considered in Chapter 2.

The commonly used method for measuring relapse and determining the timing of relapse is by comparing cephalometric radiographs of a given patient taken at different times. A review of the literature relating to cephalometery is presented in Chapter 3.

Relapse is defined and methods which have been used to assess relapse are presented in Chapter 4. The literature is replete with studies which attempt to quantify relapse with respect to time: while many show that it is often an early event, others show that it can also occur later. Timing of relapse is reviewed also in Chapter 4.

Reviews of the literature concerning factors associated with relapse following mandibular advancement are presented in Chapter 5.

Various authors have reported that the type of fixation influences relapse; accordingly, a review of the literature concerning internal fixation for osteotomies is presented in Chapter 6 and this is compared to literature relating to internal fixation for the treatment of fractured mandibles.

The reported incidence of neurosensory disturbance in mandibular advancement surgery and methods of evaluating neurosensory function are presented in Chapter 7.

As a result of the above mentioned problems associated with the bilateral sagittal split osteotomy it was decided to investigate the Inverted 'L' osteotomy as an alternative procedure for mandibular advancement. Traditionally this osteotomy has been performed via an extraoral approach which has the disadvantage of skin scaring.

The objectives of this study are, therefore,

1. to refine an intraoral approach for this osteotomy;
2. to assess the stability of the Inverted 'L' osteotomy;

3. to compare the stability with the bilateral sagittal split osteotomy;
4 to compare the incidence of neurosensory problems with the bilateral sagittal split osteotomy; and,
5. to compare the intraoral with the extraoral inverted 'L' osteotomy.

The investigation involved an assessment of 33 patients from either the South Australian Oral and Maxillofacial Surgery Unit or the private practice of R.H.B.J., who had mandibular advancement surgery performed using either an inverted 'L' osteotomy or a bilateral sagittal split osteotomy. All patients were operated on by the same surgeon. Relapse was assessed by comparing serial cephalometric records. Neurosensory testing was performed to assess mental nerve function following the orthognathic surgery .

The materials and the method relating to relapse are presented in Chapter 8, where an outline of the study design including the surgical techniques is presented. The radiographic techniques are described as are the tracing and digitizing methods, including a list of the definitions of the landmarks used.

The methodology for examining the error of the method is presented in Chapter 9. Essentially this involved a series of ten double determinations in which ten lateral ceph radiographs were randomly chosen from the study. These radiographs were traced and digitized and then the error of the method was calculated.

The methodology of the neurosensory testing is presented in Chapter 10. This involved both subjective and objective neurosensory testing using an independent clinical assistant who was blind to the surgical procedure.

The results relating to relapse following mandibular advancement are presented in Chapter 11. The investigation involved a detailed assessment of 124 lateral ceph radiographs. The subjects were divided into three groups. Group I consisted of patients who had an intraoral inverted 'L' osteotomy. Group II were patients who had a bilateral sagittal split osteotomy performed. Group III were patients who had both an extraoral inverted 'L' osteotomy and a Le Fort I osteotomy performed. Initial investigations involved assessing the magnitude of advancement and subsequent stability of point B in both the horizontal and vertical planes. Students t-test for unpaired values revealed no statistically significant sex differences in Groups I and II (Group III were all females), accordingly, males and females were pooled in Groups I and II.

The results of the error of the method are presented in Chapter 12. These results are acceptably low when compared to the reports from similar studies in the literature.

The results of the neurosensory testing are presented in Chapter 13. Only 20 patients out of the total of 33 patients presented for the neurosensory testing. Results showed that there was statistically significant less neurosensory deficit with the intraoral inverted 'L' osteotomy when compared to the bilateral sagittal split osteotomy.

A summary of the key results relating to skeletal relapse are presented in Chapter 14, and the findings of this study are discussed in Chapter 15. The conclusions drawn from the study are presented in Chapter 16.

To further investigate fixation and the use of bone grafting to the osteotomy sites an animal model, the Marino sheep is used. Appendix 1 reviews the nature of this experiment, results and conclusions drawn from them.

II

REVIEW OF THE LITERATURE

CHAPTER 2

MANDIBULAR DEFICIENCY

2.1 DEFINITION

Mandibular morphology varies widely throughout the world not only between different ethnic groups but also within each ethnic group (Rowe 1960). For each group there is a facial pattern which represents facial harmony. Excessive, deficient, or asymmetrical growth beyond those limits commonly observed invokes either a sense of displeasure or constitutes a deformity according to the degree of departure from the accepted standard which has taken place.

In order to diagnose mandibular deficiency in an individual, clearly one needs a classification system based on observations or measurements and the mean and range of values of the group to which the individual belongs. Historically, Edward Angle 1907 introduced a morphological classification of the bite based on the relative relationship of the maxillary and mandibular first molars. He divided the population into three groups or classes:

Group I. The relationship between the molars in the upper and lower jaw is normal mesio-distal.

Group II. The position of the mandibular molars is distal in relation to the maxillary molars, compared with normal occlusion.

Subdivision 1. Protruding upper incisors.

Subdivision 2. Receding upper incisors.

Group III. The position of the mandibular molars is mesial in relation to the maxillary molars, compared with normal occlusion.

Angle assumed that the variation obtained with molar occlusion was due to the way in which the lower jaw as a whole accommodated itself to the upper jaw. In the case of group II (Class II) the lower jaw is deficient in the anterior-posterior plane.

Bjork (1947) disagrees with Angle in that he felt that the Class II malocclusion could also be caused by maxillary excess in the anterior-posterior plane with or without mandibular deficiency. Rosenblum (1995) undertook a study to determine the nature of the underlying skeletal pattern of Class II malocclusions in a North American sample by using computerised cephalometric programs. He found that 27% of the sample had mandibular retrusion with 56.3% having maxillary protrusion.

Kerr et al (1994) looked at a sample of 124 Scottish 10 year old boys equally divided among the Angle classes. Looking at cephalograms he found mandibular form and size to be similar for all three classes, thus he concluded that the malocclusions were due to the position of the mandible relative to the cranial base, with the possible exception of the Class II div. 2 which he felt is largely a dentoalveolar rather than a skeletal entity.

Mandibular deficiency leads to a characteristic protrusion of maxillary teeth and deficiency of the chin, according to Bell et al. (1980). The terminology is confusing as some terms mean different things to different authors and there are many synonyms. Trauner et al (1957) use the terms retrognathia and distocclusion interchangeably to describe mandibular deficiency in the anterior-posterior plane.

Hinds and Kent (1972) prefer to use the terms mandibular retrognathia and micrognathia instead of mandibular deficiency. They consider mandibular retrognathia to imply a normal sized mandible in a retruded position. They define micrognathia as a small jaw.

Wolford et al (1978) note that the idiopathically deficient mandible has been referred to as mandibular retrognathism, retrognathism, mandibular microgenia, mandibular retrusion, skeletal Class II and simply Class II malocclusion. They propose however that this spectrum of deformity is best described as the Mandibular Deficiency Syndrome. This excludes identifiable syndromic conditions with a deficient mandible such as Pierre Robin Anomaly or Treacher Collins Syndrome.

Rakosi (1982) comments that in the retrognathic type of mandible the ascending ramus is narrow, as is the condyle in the antero-posterior direction. The coronoid process is shorter than the condylar process, the symphysis narrow. The angle between the axis of the lower central incisors and the mandibular plane is greater than 90 whilst sn-mp angle is 30° - 40°.

2.2 CLASSIFICATION OF MANDIBULAR DEFICIENCY

The pathognomonic features of mandibular deficiency are protrusion of the maxillary teeth and deficiency of the chin; and various attempts at classification of mandibular deficiency exist.

There are many potential causes for mandibular deficiency, one classification could thus be based on cause: Bell et al 1980 listed the following (Table 2.1).

Table 2.1 Aetiology of mandibular deficiency

Congenital

1. Intrauterine moulding
2. Condylar agenesis
3. Paralysis of masticatory muscles
4. Syndromes
    - Hemifacial microsomia
    - Pierre Robin
    - Treacher Collins
    - Goldenhar
    - Progressive hemifacial atrophy
    - Mobius
    - Progeria
    - Micrognathia; polydactyl; genital; anomalies
5. Idiopathic small mandible

Acquired

1. Perinatal trauma
2. Infection
3. Surgery
4. Radiation stunting
5. Mandibular ankylosis during childhood
6. Trauma during childhood
7. Juvenile rheumatoid arthritis

Bjork (1947) describes three main types of 'maxillary overbite' :

1. a relative difference in maxillary and mandibular basal prognathism.
2. A relative difference in the alveolar prognathism.
3. An alteration in the inclination of the incisors

(Figure 2.1)

Mandibular deficiency may occur in isolation or be associated with other dentofacial deformities, it may be symmetrical or assymetrical such as hemifacial microsomia (Rowe 1960).

Figure 2.1 The three main types of an incisal Class II relationship shown by the broken line.

(a) A relative difference in basal prognathism.

(b) A relative difference in alveolar prognathism.

(c) Inclination of the incisors.

(Modified from Bjork 1947)

2.3 INCIDENCE OF MANDIBULAR DEFICIENCY

Trauner and Obwegeser (1957) note that in many parts of the world mandibular deficiency is encountered more frequently than prognathism.

There are few studies in the literature on the incidence of mandibular deficiency, there are however numerous studies on the incidence of Class II malocclusions and these give us an estimation of the incidence of mandibular deficiency.

Lawrence et al (1985) noted that only 7% of Class II patients had horizontal maxillary excess. The other 93% had horizontal mandibular deficiency or a combination of maxillary and mandibular deficiency.

It is known that mandibular deficiency is common among Northern European and American populations and rarer among Asian populations. Data from a large scale U.S. Public Health Service survey cited in Bell et al 1980 concluded that 20% of the United States population had a Class II dental relationship. Bell estimates from these figures that about 5% of the United States population has skeletal mandibular deficiency and of these he believes that 20% (ie 1% of the total population) would require surgery to correct the condition satisfactorily.

Mandibular growth is slower that maxillary growth in younger children, mandibular growth also lasts longer, so that a degree of mandibular deficiency is normal for younger age groups (Bjork and Skieller, 1983).

2.4 INDICATIONS FOR TREATMENT OF MANDIBULAR DEFICIENCY

The main indications for treatment of mandibular deficiency are to improve function or appearance or a combination of both. Archer (1961) noted that patients with pronounced mandibular deformities may exhibit psychic disturbances. The patients become introverts, acquire inferiority complexes, are morose, and suffer mental anguish. Interference with normal employment and social success may result. Functional disabilities may arise, including speech difficulties, improper mastication and inadequate nutrition. However he notes that few patients seem to be the worse physically as a result of their deformity, and the main reason for seeking surgery is that they are sensitive about their appearance. Kiyak and Bell (1991) have shown that in a psychosocial context malocclusion can affect employability, interpersonal relationships, and, accordingly self esteem.

Sambrook (1989) in a study investigating the psychological aspects of dentofacial surgery patients showed that the patients perception of the problem is not necessarily proportional to the degree of deformity.

Throckmorton et al (1995) in a well designed study compared 24 female patients with mandibular deficiency requiring surgical correction with a control group of 26 Class I females. Preoperatively the patients with mandibular deficiency were found to have maximum isometric bite force less than half that of the control group, however, two years post operatively the bite forces in the two groups were approximately equal. The average magnitude of mandibular advancement was 7.3 mm. The authors concluded that mandibular advancement produces some significant functional benefits.

2.5 TREATMENT OF MANDIBULAR DEFICIENCY

Treatment options available to correct mandibular deficiency include:

(i) no treatment at all;

(ii) orthodontic camouflage;

(iii) surgery alone; and

(iv) surgery in combination with orthodontics.

Treatment for mandibular deficiency is dependent on a number of factors which include:

(i) degree of dentofacial deformity;

(ii) patient perception of the problem; and

(iii) treating clinician(s) perception of the problem.

Bell et al (1980) believe that an ANB angle of 6° or more or an AB difference of 6 mm or more is too great a jaw discrepancy to be compatible with normal dental occlusion. Orthodontic treatment has been available for many years and has had two main aims: first, to encourage favourable growth of the mandible, and, second, to camouflage the deformity. Whether mandibular growth can be stimulated is controversial, Bell concludes that large scale stimulation of mandibular growth does not seem possible. Successful orthodontic treatment usually consists of a combination of retraction of the maxillary incisors and protraction of the mandibular incisors.

Reitzik (1980) notes that treatment of Class II malocclusion by orthodontics alone for more than a minor deformity may lead to an unaesthetic facial form.

Bell et al (1968) listed the following as orthodontic limitations and dentofacial characteristics of class II malocclusions in adults which may be indications for surgery:

1. Cessation of jaw growth and development.
2. Unwillingness of the patient to wear orthodontic appliances for the necessary period of time.
3. Skeletal deformity too great for orthodontic treatment alone.
4. Excessive maxillary gingiva exposed when the patient smiles.
5. Orthodontic intrusion of teeth is difficult.
6. Prolonged orthodontic treatment contraindicated by periodontal condition.
7. Missing posterior dentition which would normally serve as anchorage teeth.
8. Socioeconomic considerations.

A study by Proffit et al (1992) found that surgery is likely to be needed for successful treatment of the malocclusion if the overjet is greater than 10 mm, especially if the distance from pogonion to nasion perpendicular is 18 mm or more, mandibular body length is less than 70 mm, or facial height is greater than 125 mm.

Tucker (1995) states that a combination of orthodontics plus orthognathic surgery for treatment of Class II malocclusions, when associated with mandibular deficiency, often has improved results compared with orthodontic treatment alone. He feels that strong consideration of surgical correction of mandibular deficiency should be based on the following questions:

(1) Do the patients goals for treatment place a high priority on facial aesthetics? Or should those patients who are not particularly concerned with aesthetics but for whom orthodontic camouflage may have a worsening effect on their aesthetics, be considered for orthognathic surgery? This may include patients with an obtuse nasolabial angle, with lack of upper lip support, long lower face height, and a large nose all of which may become more noticeable as a result of orthodontic treatment alone.

(2) Are the movements required in excess of that correctible by orthodontics alone?

(3) Could a combined approach result in a reduction in treatment time?

(4) Is there adequate patient compliance? By this he implies that if a patient's compliance is poor would a better result occur if surgery was included.

(5) Do the benefits of surgery outweigh the risks?

Thomas (1995) notes that there would appear to be ample justification for correcting Class II malocclusions, but believes that there are flaws in the process of selecting treatment options. He believes that while there is little disagreement when considering patients at the extremes of the classification, mild Class II problems can be orthodontically corrected while severe discrepancies require orthognathic surgery, problems seem to occur when the patient falls into what he calls the "grey zone" and might be treated by either option. To aid in treatment planning they propose a treatment planning process which involves data collection including patient interviews, clinical examination, radiographic studies, standardised photographs and dental models. This information is analyzed to produce a series of findings that can be prioritized according to the patients concerns with maximum efficiency and minimum morbidity. This process may include treatment simulation using computer imaging and model surgery.

2.6 SURGERY FOR THE TREATMENT OF MANDIBULAR DEFICIENCY

Surgery to correct mandibular deformity is not a recent innovation, Hullihen 1849 cited in Rowe (1960) performed an operation for the correction of an anterior openbite deformity. This procedure employed resection of part of the alveolar process .

There are other descriptions of mandibular surgical procedures in the nineteenth century literature mainly concerned with the correction of mandibular excess. Caldwell (1968) notes that surgery to correct mandibular deficiency has always been a more difficult problem technically than correction of prognathism because there is minimal bony substance in which to perform the osteotomy and there may not be adequate investing soft tissue to cover the surgically elongated jaw.

Blair in 1907, cited by Rowe (1960), gives one of the first accounts of surgery for correction of mandibular deficiency, he describes bilateral osteotomy of the ramus using a gigli saw followed by advancement of the distal fragment into the required position.

Blair, in an address to a dental society group in 1907 cited in Archer (1961), summarised the purpose of orthognathic surgery as follows:

"If called upon, our endeavour should be to set the bones on the position that will ultimately give a useful occlusion, and the most symmetrical facial outline. Occlusion must be an end, not a guide, while good mechanical, and not ideal occlusion should be the object."

Hofer (1942) cited in Obwegeser (1964) describes a technique where the alveolus between the mental foramina was separated from the body of the mandible, and placed in a forward position and more inferior position for the correction of the excessive overbite and overjet. The gap could be bone grafted with bone taken from the inferior site of bone removal (Figure 2.2). Hofer's technique obviously resulted in an edentulous gap bilaterally and was also only suitable for cases where the chin tip position was already preoperatively in normal relationship to the rest of the facial skeleton

Surgery to correct mandibular deficiency was popularised by Trauner and Obwegeser (1957). They describe four techniques for the correction of 'retrognathia'.

1. Retrocondylar Cartilage Implantation. (Figure 2.3)

   This consists of a pre auricular incision to gain access to the mandibular condylar head, the mandible is then advanced to the desired position and a block of costal cartilage is then wired in situ between the condylar head and the anterior wall of the auditory meatus

2. Simple Genioplasty (Figure 2.4)

   In cases where there is satisfactory occlusion a simple chin enlargement is advocated.

Figure 2.2 'The mandibular osteotomy described by Hofer. (modified from Obwegeser 1964)

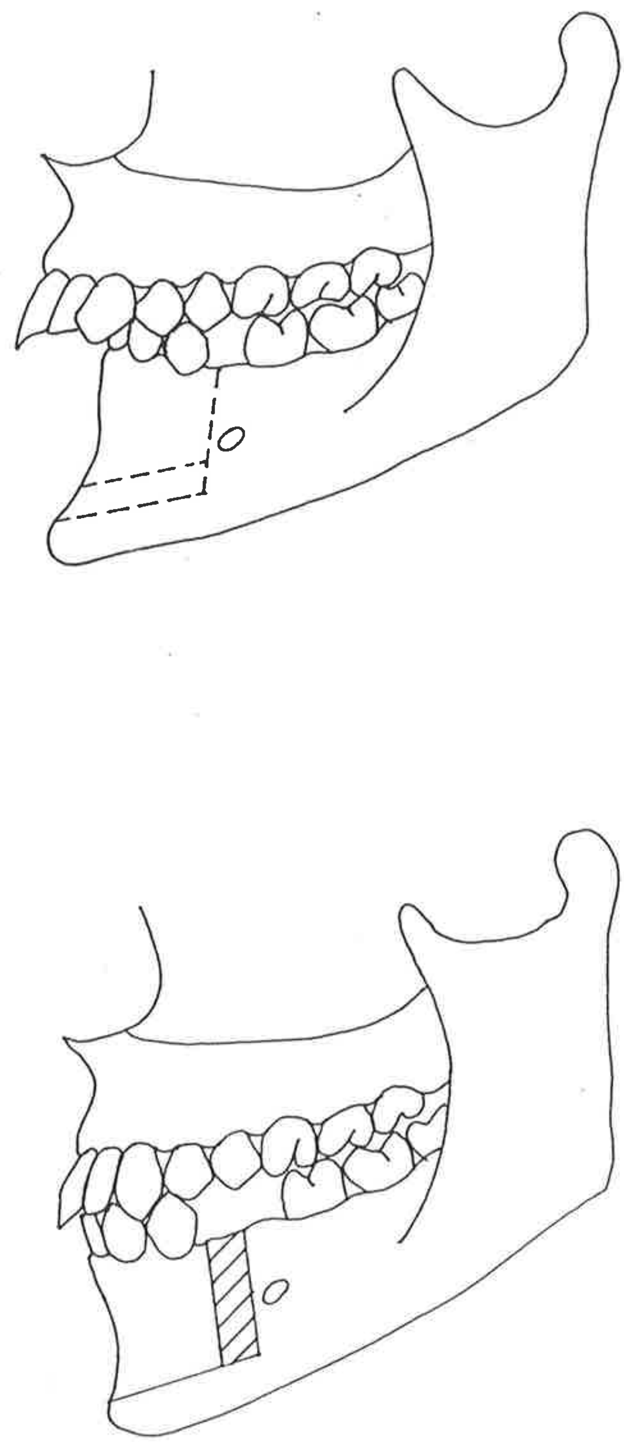


Figure 2.3 Retrocondylar cartilage implantation.
(Modified from Trauner and Obwegeser 1957)

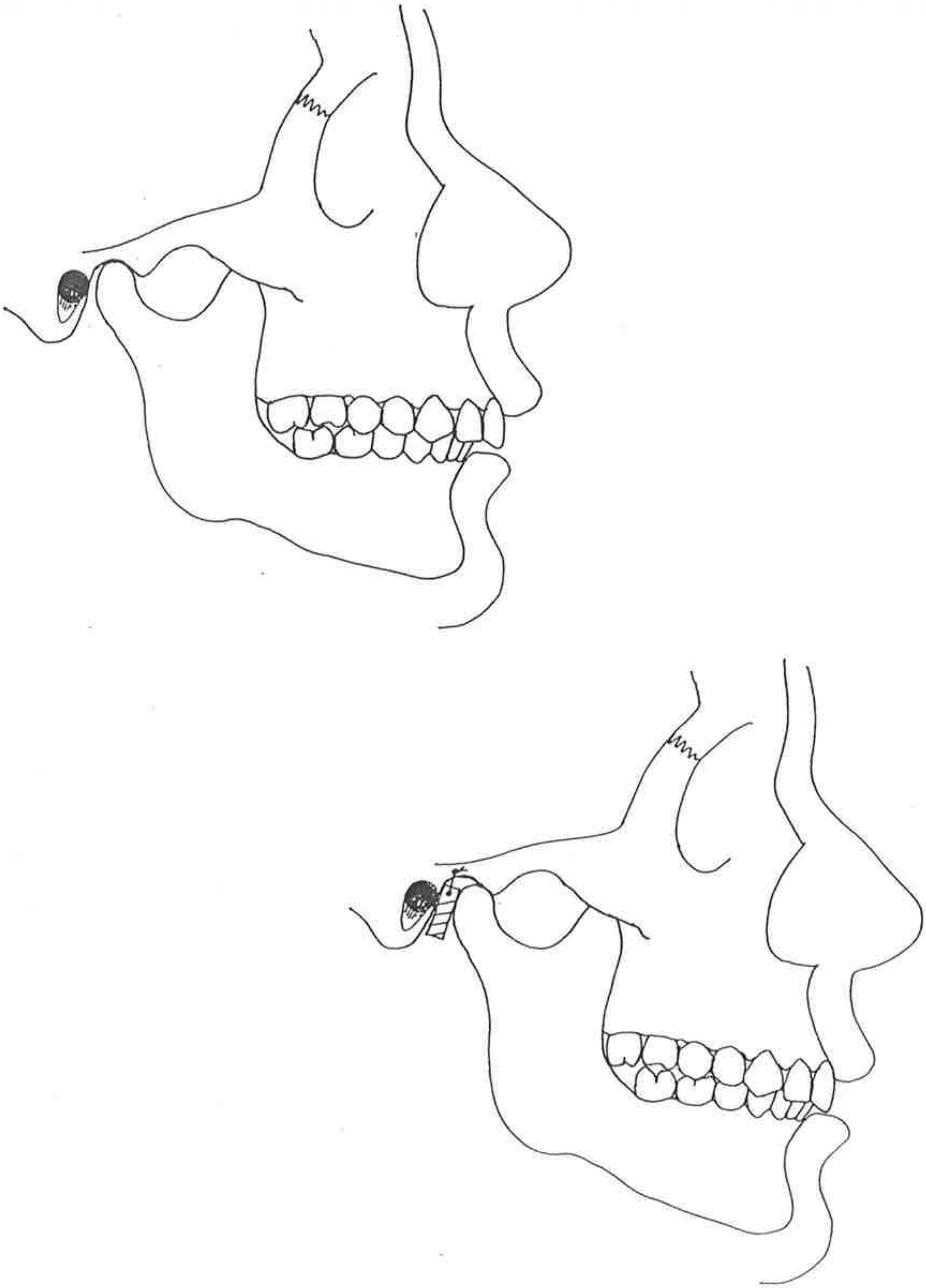
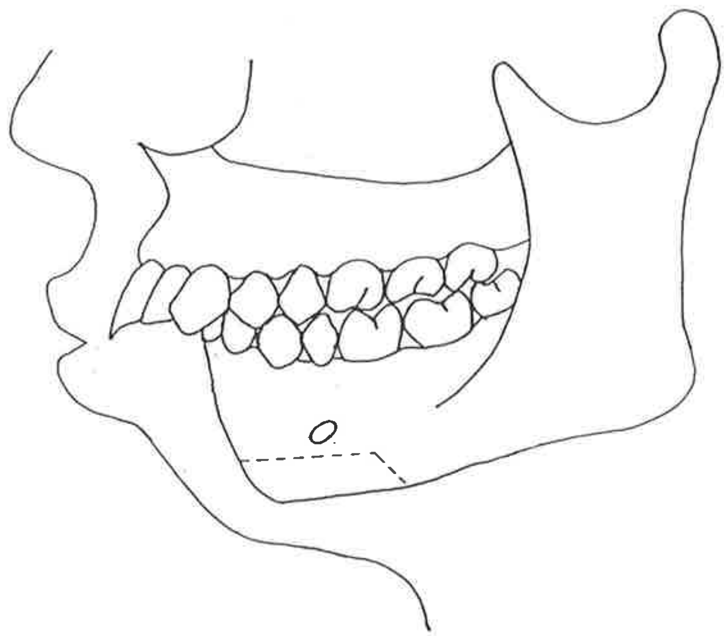
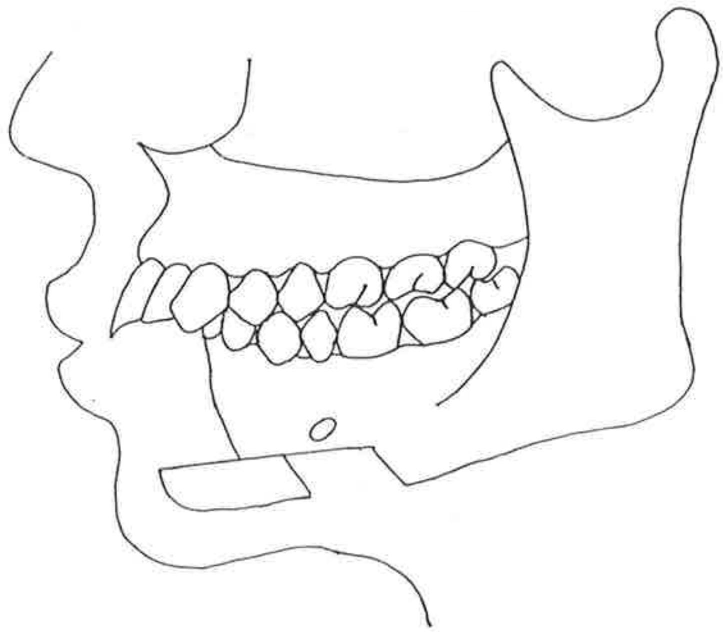


Figure 2.4 Advancement genioplasty

(Modified from Trauner and Obwegeser 1957)





3. Osteotomy in the Ascending Rami (Figure 2.5)

For cases of mandibular deficiency which are too great to be corrected by retro condylar cartilage implantation the ascending rami osteotomy is indicated.

The ascending ramus is split via an intra oral route to separate the lingual and buccal cortices so that the two parts can be manipulated without loss of contact. The two fragments are then secured with a wire placed trans cutaneously, and the patient is placed into inter maxillary fixation post operatively.

4. Osteotomy in the Horizontal Rami (Body Osteotomies)

This is an osteotomy which the authors only mention briefly, attributing it to Converse et al (1954). It involves a cut through the posterior mandibular body and bone grafting. Trauner and Obwegeser do not give their opinion of this method as they report that they had not employed it.

2.6.1 The sagittal split osteotomy

Modifications to the osteotomy in the ascending rami were proposed by authors in the ensuing years. Dal Pont (1961) advocated making the inferior cut vertically through the buccal cortex to increase the area of bone in contact between the lingual and buccal cortices (Figure 2.6). His original description was for use in mandibular setbacks however the technique can be applied effectively for advancements.

Hunsuck (1968) modified the sagittal splitting technique further by only extending the superior cut as far posteriorly as the lingula. (Figure 2.7)

Figure 2.5 Osteotomy in the ascending rami.
(Modified from Trauner and Obwegeser 1957)

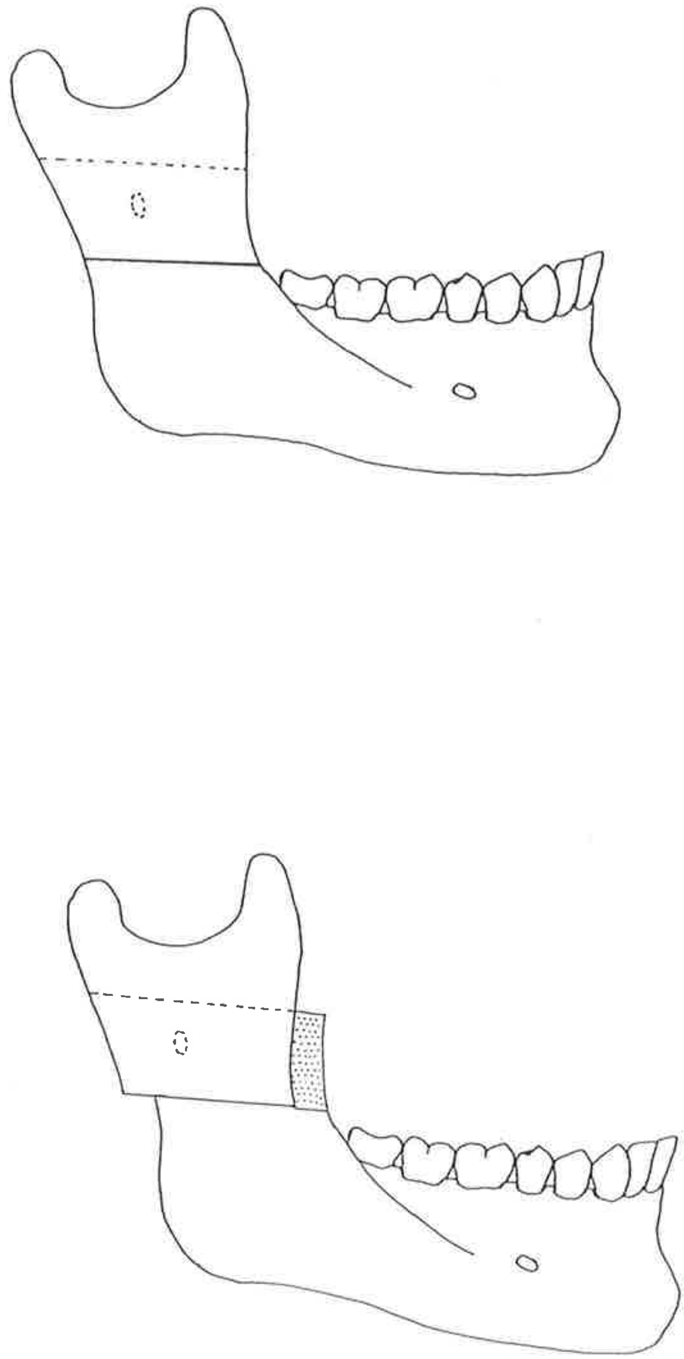


Figure 2.6 Dal Pont's modification of the ascending ramus osteotomy (1961)

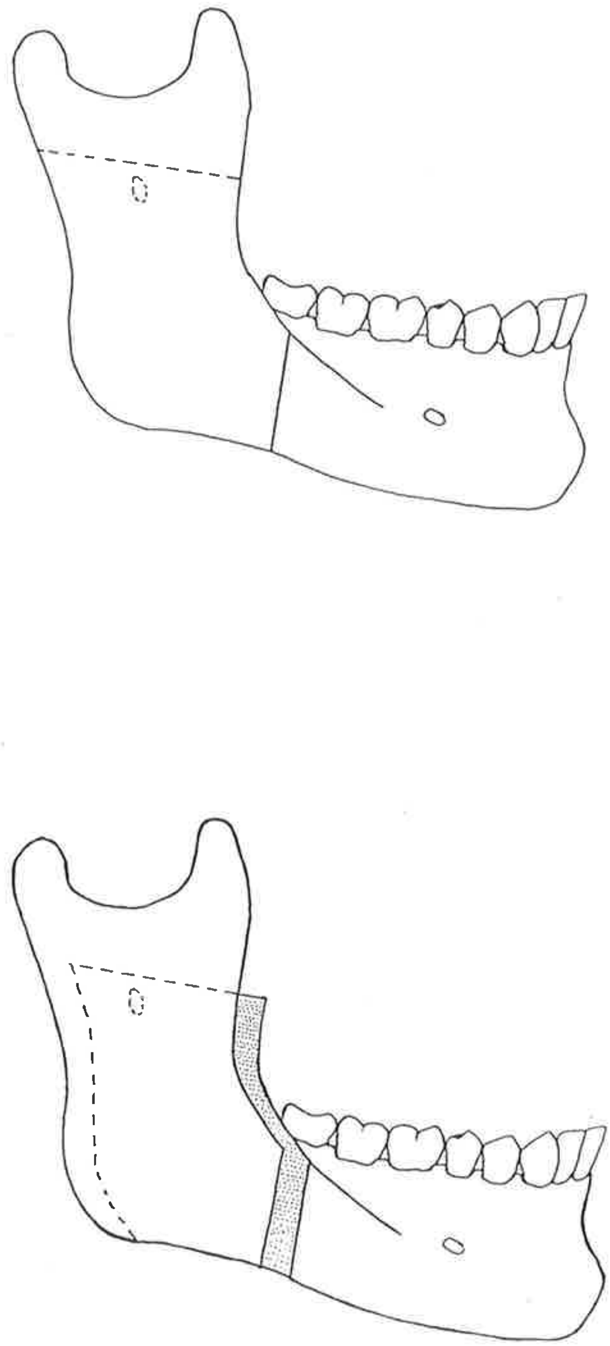
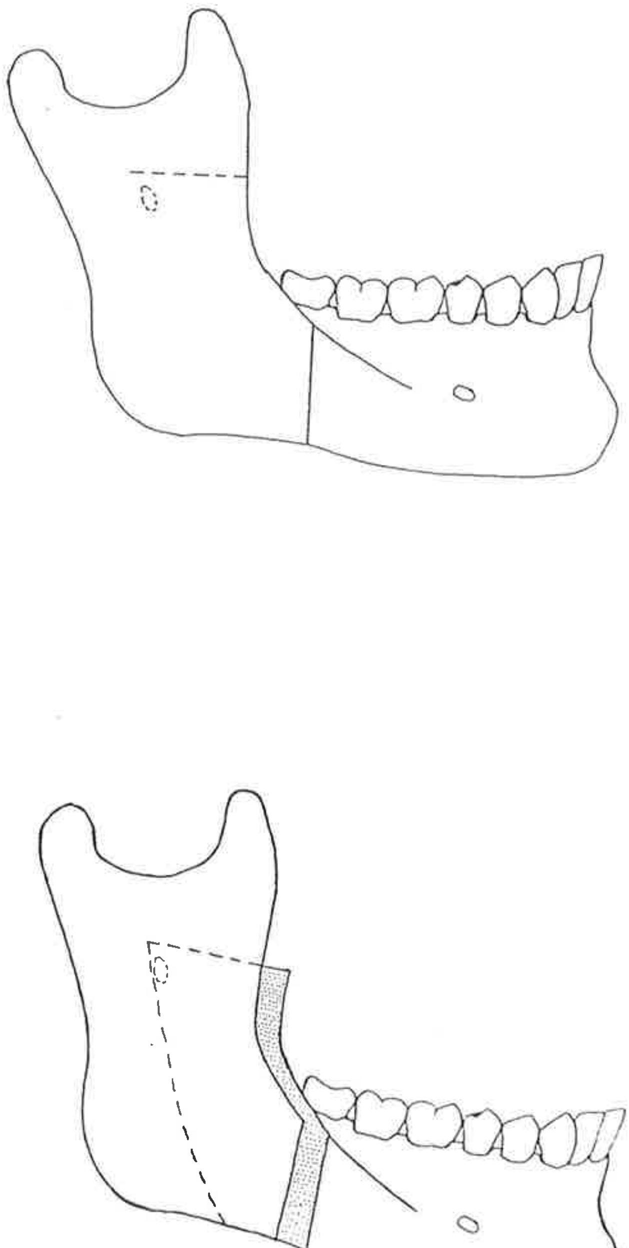
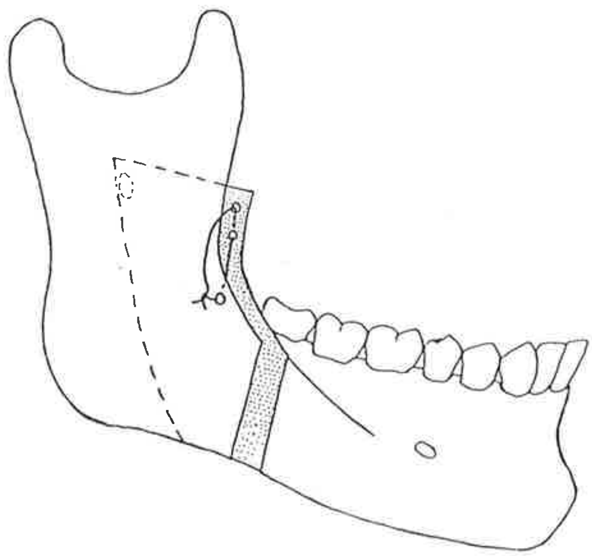


Figure 2.7 Modification of the ascending ramus osteotomy as described by Hunsuck (1968)



Epker (1977) noted that the sagittal split osteotomy of the mandible was being used with increasing frequency but noted that there were untoward sequelae associated with the procedure. He accordingly suggested some modifications to reduce the incidence of complications, essentially he reduced the amount of stripping of soft tissue. If the mandible is to be advanced, the major portion of the medial pterygoid is left attached to the proximal segment. If the mandible is to be set back, the pterygoid muscle is easily stripped from the proximal segment under direct vision through the split. In an effort to help seat the condyles Epker advocates placing holes for wires high in the distal and low in the proximal segments. (Figure 2.8)

Figure 2.8 Modification of the ascending ramus osteotomy as described by Epker (1977)



The next step in the evolution of the sagittal split osteotomy was the use of bone screws for 'rigid fixation' these were advocated by Spiessl (1974). Initially IMF was used in addition to rigid fixation but, with time, many surgeons have used rigid fixation alone. (Chapter 6).

Among the advantages cited for rigid fixation are that the condylar position and mandibular function can be confirmed at the time of surgery while the patient is still under general anaesthetic, Rubens et al (1988), Van Sickels et al (1985), Wolford et al (1987). These authors also note that early release of IMF increases patient comfort, allows for better oral hygiene and has been thought to contribute to better speech and nutrition in the post operative period.

Rubens et al (1988) reports that rigid fixation without IMF allows bimaxillary surgical procedures in conjunction with nasal procedures to be performed without airway embarrassment.

Worrall (1994) investigated the effects of IMF in a group of 13 patients who had either orthognathic surgery or treatment of a fractured jaw (mandible or maxilla) treated with IMF. When compared to a similar group of patients treated by rigid fixation without intermaxillary fixation, the patients in IMF had lost on average 1 kg more at six weeks this is however an inconsequential loss.

Trauner and Obwegeser's osteotomy of the ascending ramus has thus evolved into what we now commonly know as the bilateral sagittal split osteotomy. This is a popular and versatile procedure, but it does still however have problems associated with relapse and sensory nerve injury, these will be discussed in Sections 4.5 and 7.5 respectively.

Kitajima (1989) describes the high supraforaminal split, which he claims has the potential advantage of reducing the danger of injury to the mandibular nerve. Interestingly, the osteotomy cuts are placed in the same position as Trauner and Obwegeser's original description, however the technique is quite different and involves placing a vertical cut just medial to the lateral cortex of the ramus, thereby minimizing trauma to the nerve.

2.6.2 The vertical ramus osteotomy

Small and Rae (1963) describe a modification of the vertical subsigmoid osteotomy for mandibular advancement. (Figure 2.9) The technique involves an extraoral approach to the mandibular ramus, making the vertical subsigmoid cut and removing the inferior end of the proximal segment which is then placed as a bone graft to the osteotomy site once the mandible has been advanced. They report that there is seldom the need to harvest bone from elsewhere. This technique has not gained wide acceptance.

2.6.3 'L' , Arcing and 'C' osteotomies

Caldwell et al (1968) describe the vertical 'L' and 'C' osteotomy for mandibular advancement, these procedures allowed bone to be in contact following advancement of the distal segment. (Figure 2.10)

Hawkinson (1968) describes the arcing osteotomy and suggests it is suitable for advancements where there are also rotations, such as in closing anterior open bites. (Figure 2.11)

2.6.4 The inverted 'L' osteotomy

The inverted 'L' osteotomy (Figure 2.10) was first described by Wassamund in 1927 according to Dattilo et al (1985). The original description used an extraoral approach and consisted of a vertical and a horizontal cut of the ramus above and behind the lingula, thus avoiding the inferior alveolar nerve. The distal segment is then placed into the preplanned position and IMF applied. Since the original description was for mandibular setbacks the proximal and distal fragments would overlap and therefore a bone graft was not required.

Figure 2.9 Vertical osteotomy for retrognathia
(Modified from Small and Rae 1963)

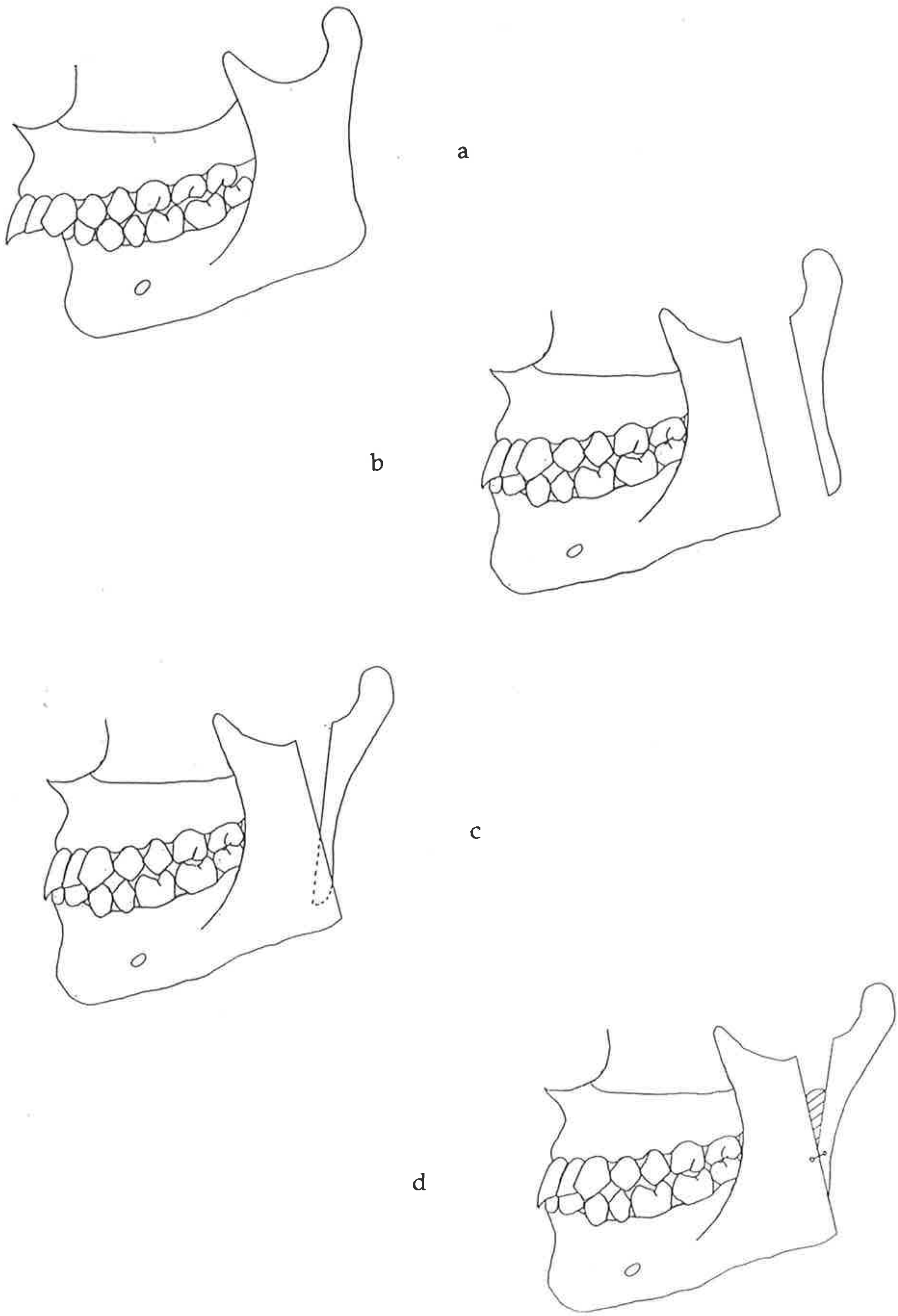


Figure 2.10 Ramal osteotomies

(a) Vertical 'L'osteotomy after Caldwell et al 1968

(b) 'C' osteotomy after Caldwell et al 1968

(c) Inverted 'L' osteotomy, after Trauner and Obwegeser 1957

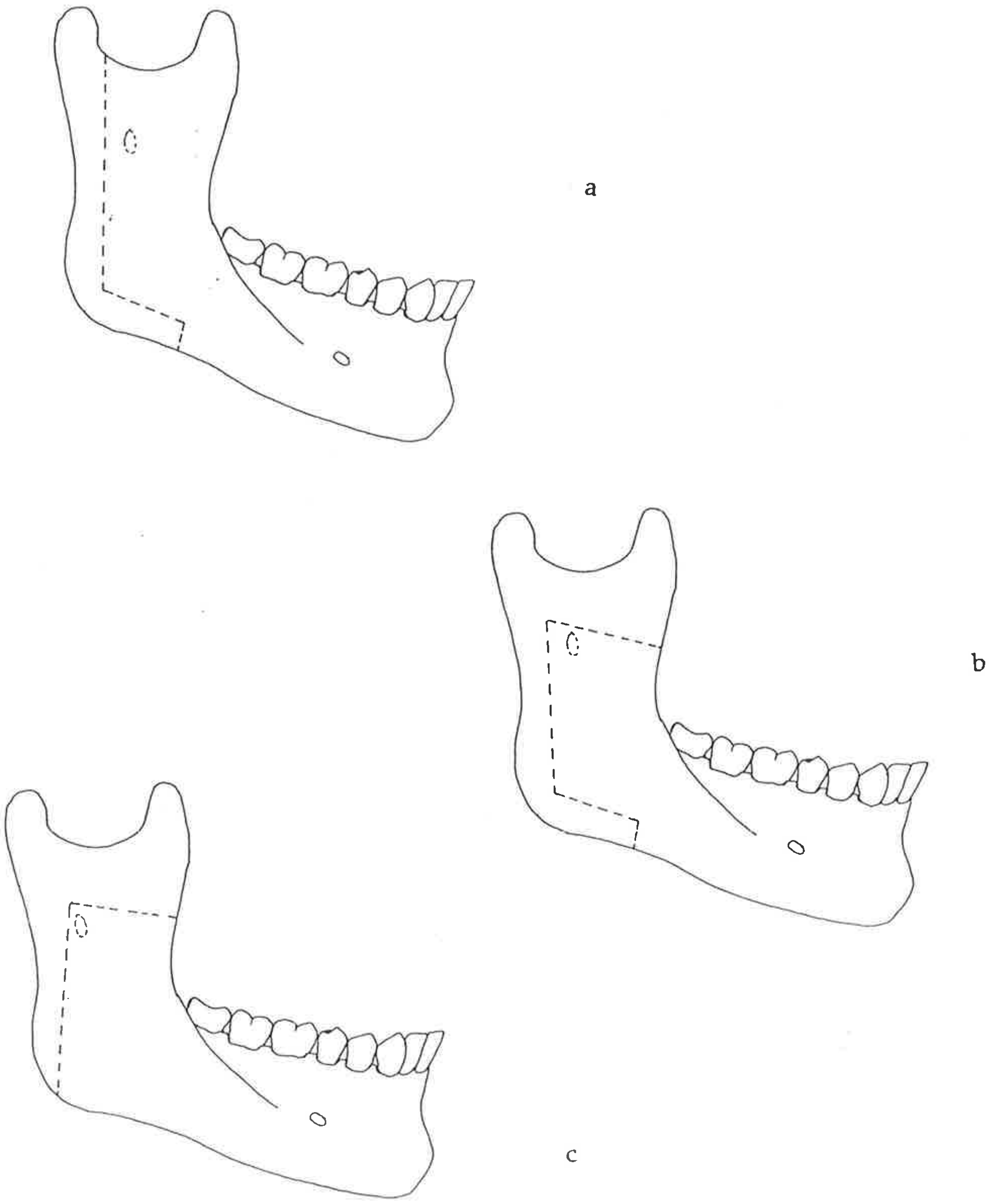
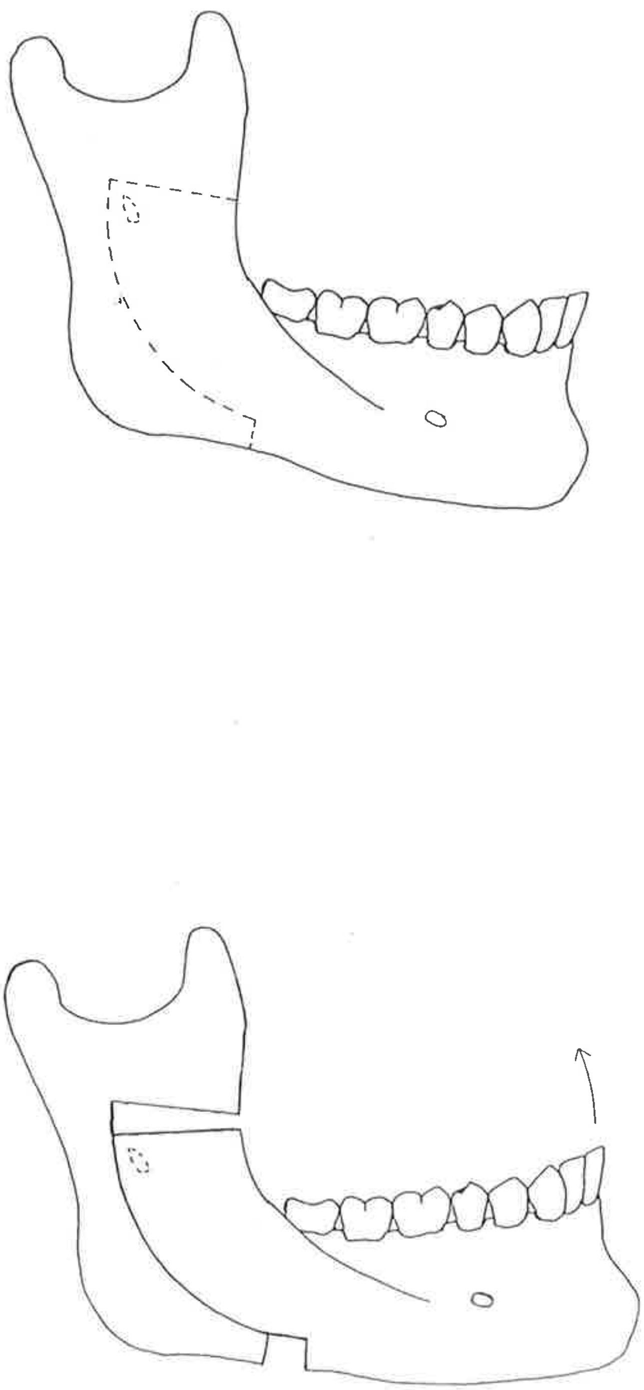


Figure 2.11 The arcing ramus osteotomy after Hawkinson (1968)



The first account of the inverted 'L' in the English literature is an account by Trauner and Obwegeser (1957), they describe making the horizontal bone cut via an intraoral incision and then the vertical bone cut is made via an extraoral incision. The extraoral incision is made 3 cm in length, running 1.5 cm below the angle of the jaw. The use of an instrument called a Wolf's gnathotome is suggested for the vertical bone cut and a Lindeman bur is used for the horizontal cut. The technique is described only for setbacks and once the distal fragment is in the preplanned position it is secured with a horizontal circumferential wire and the patient is placed into wire IMF for three to four weeks. This is then replaced by elastic IMF for a further four weeks.

Levine and Topazian (1976) describe an intraoral approach using the inverted 'L' osteotomy for mandibular setbacks. They use a Stryker oscillating saw with a right angled blade to perform the vertical cut and a Lindeman bur for the horizontal cut.

Farrell and Kent (1977) used the inverted 'L' osteotomy for both mandibular setbacks and advancements. They also report that two cases were performed as intraoral procedures but do not describe the technique by which this was accomplished. The inverted 'L' osteotomy was used as the surgical procedure when preoperative case assessment indicated a need for an increase in posterior facial height. It was also used for closing skeletal open bites.

Henderson et al (1985) reported on the use of the inverted 'L' osteotomy for mandibular advancements and suggests that it is particularly suited to mandibular advancements where there is deficient ramal width. Henderson reported that access can be either intraoral or extraoral, but prefers the latter. His technique involves maintaining muscular attachments to the proximal fragments but reports that the periosteum may need splitting. When the jaw is brought forward L-shaped corticocancellous grafts are taken from the iliac crest with a preformed template and inserted upside down into the defects in the mandibular rami, the patient is then placed into IMF for an unspecified number of weeks. They note that a bone graft may substantially recontour the deficient angle in micrognathic cases.

2.6.4.1 Bone grafting and fixation of the inverted 'L' osteotomy

The specific purpose of the bone grafts is to induce osteogenesis and to provide a matrix on which ossification can take place, creating new bone, according to Boyne (1970). The iliac crests (anterior and posterior) are commonly used sites for harvesting such bone, although there is much literature on sites for harvesting bone. Other sites for harvesting bone include the cranium (Harsha et al., 1986), rib (Laurie et al., 1984), the tibia and metatarsals. (Braun and Sotereanos,1984). Braun and Sotereanos (1984) suggest that too little attention has been paid to use of grafts from anatomically adjacent and biologically similar donor sites. They present a case of mandibular deficiency which was corrected using an inverted 'L' osteotomy, the bone graft being harvested from the buccal plate of the mandible. Another case is presented by them where bone is harvested from the chin, a technique also advocated by Jensen et al. (1995).

Reitzik (1980) used an extraoral approach to the ramus to perform an inverted 'L' osteotomy for mandibular advancements and following advancement of the proximal fragment he placed rigid fixation in the form of a vitallium mesh plate and screws, and the gap created was then bone grafted using cancellous chips from the iliac crest. Dattilio et al (1985) reports that the inverted 'L' osteotomy is suitable for closing anterior open bites and describes an extraoral approach.

In an effort to control the position of the proximal fragment Van Sickels et al (1990) describe the use of a condylar positioning plate in a series of patients in which the mandible was set back using an intraoral inverted 'L' osteotomy. The condylar positioning plate was a nine hole vitallium plate placed from the zygomatic buttress of the maxilla to the lateral surface of the mandible in the region of the coronoid process. It was placed prior to completion of the bone cuts with the teeth in centric occlusion and removed once rigid fixation was placed across the osteotomy sites.

2.6.4.2 The Inverted 'L' as an access osteotomy

Flood and Hislop (1991) describe the use of the inverted 'L' osteotomy as an access osteotomy to approach tumours of the para pharyngeal space. Among its advantage over other approaches they note that the inferior dental nerve is preserved and that fixation can be achieved by placing two miniplates.

2.7 COMPLICATIONS OF MANDIBULAR ADVANCEMENT SURGERY

2.7.1 INTRODUCTION

Although frequently used the word 'complication' is rarely defined in a surgical context. Dorland's medical dictionary (Agnew et al 1965) defined complication as a disease or diseases concurrent with another disease. This is an inadequate definition because a surgical complication has two implications, it is an unexpected event and it has untoward effects.

Complications of mandibular surgery have existed since the inception of the surgery itself. Blair, as we have reported, was the first surgeon credited with performing surgery for the correction of mandibular deficiency. Hinds (1957) cites a report by the dentist of one of Blair's first patients which describes how the postoperative course was fraught with much anxiety and difficulties such as problems with immobilization, infection, and delayed union. Despite technical refinements and widespread use, surgical lengthening of the mandible has not been uniformly successful according to Barer et al (1987).

Some complications will be unique to mandibular advancement surgery, however most are problems which occur both in mandibular advancement surgery and in mandibular setback surgery. The literature on complications of mandibular surgery in general is reviewed, and then the problems which are unique to mandibular advancement surgery are reviewed.

In the early literature there are many reports of complications of mandibular surgery, for example Hensel (1937) stated that with all mandibular procedures there were one or more serious complications due to:

1. Hazardous or uncertain techniques.
2. Impairment of mandibular function.
3. Oral contamination of wound infection.
4. Injury to parotid gland or facial nerve.
5. Section of important nerves.
6. Malunion.
7. Nonunion and osteomyelitis.
8. Devitalised or lost teeth.
9. Risk of scars from wound infection.
10. Prolonged disablement.
11. Uncertain results.

Such reports may have been the reason that mandibular surgery was slow to gain popularity and acceptance. Clearly as surgical techniques were refined and as surgeons gained experience with the new techniques, the rate of complications decreased. Complications can be divided into those that occur intraoperatively, immediately postoperatively and those which are delayed.

2.7.2 INTRAOPERATIVE COMPLICATIONS

Van Merkesteyn et al (1987) reports the rate of intra operative complications as being 25.8% with the bilateral sagittal split osteotomy and 11.8% in the vertical ramus osteotomy.

Table 2.2 Complications occurring in 161 mandibular ramus osteotomies from Van Merkesteyne et al (1987)

	Technique			
	S.S.O.*	**V.R.O.****	**Other**	**Total**
Complication				
Lesion inferior alveolar nerve.	7	-	1	8
Fracture.	5	-	-	5
Incomplete sectioning.	14	-	-	14
Erroneous bone cut.	2	1	-	3
Dislocation proximal segment.	1	3	2	6
Haemorrhage inf. alv. artery.	1	-	-	1
Haemorrhage facial artery.	1	-	-	1
Herniation buccal fat.	1	-	-	1
Total	32	4	3	39

***S.S.O.** - Sagittal Split Osteotomy

****V.R.O.** - Vertical Ramus Osteotomy

Hogeman (1951) reported that when performing horizontal osteotomies of the vertical ramus occasionally there was profuse bleeding from the posterior facial vein which could be controlled quickly by pressure on the wound.

Behrman (1972) published the results of a questionnaire circulated to surgeons concerning complications of the sagittal ramus osteotomy. Thirty eight percent of respondents reported haemorrhage as a complication, half of these described the haemorrhage as severe. In two cases the haemorrhage required ligation of the external carotid arteries. In one case the bleeding was so severe that the surgery had to be aborted. Blood transfusions were required for several patients. The respondents believed the source of the haemorrhage to be from lacerations of the maxillary, facial or inferior alveolar arteries, however in Berhman's experience the most common source of excessive bleeding was the posterior facial vein. One needs to remember that at this point in time orthognathic surgery was still in its infancy and few surgeons had substantial experience in the field. This may account for the high rate of complications.

Lanigan et al (1991) reports on 21 cases of haemorrhage following mandibular osteotomies, he believes that haemorrhage following orthognathic surgery is usually the result of insufficient surgical haemostasis rather than coagulopathies. Excess bleeding is more commonly encountered with maxillary surgery than with mandibular surgery. Nine of the twenty one cases presented were as a result of mandibular advancement surgery and in these cases the most common vessel involved was the posterior facial vein in contrast to mandibular set-back surgery in which the commonly involves vessel was the maxillary artery.

Van de Perre et al. (1996) found that major blood loss was a rare event with orthognathic surgery in a retrospective study of 2049 patients who underwent one or two jaw surgery. Twelve patients who had bimaxillary surgery required transfusion of two or more units of blood but no patients having only mandibular surgery required transfusion.

A problem unique to mandibular advancement surgery is ensuring that the condyles are seated in the fossa intraoperatively, otherwise when fixation is released immediate relapse will result (Hall et al, 1975; Isaacson, 1978; Ware and Taylor, 1968; Kohn, 1978; Lake et al., 1981; Hase, 1988). This is an example of an intraoperative complication which may not become apparent until a later period.

Isaacson et al. (1978) noted that during mandibular advancement surgery the condyles could be displaced anteriorly up to 2.7 mm and inferiorly up to 3.7 mm. There were two schools of thought on how to overcome the problem. Isaacson (1978) suggested using no intraosseous fixation and simply placing the patient into IMF, they report that the condyles will in this way seat themselves. Epker approaches this problem differently and uses IMF plus intraosseous wiring, placing holes for wires high in the proximal and low in the distal segment thus tending to actively seat the condyles. (Figure 2.8) Further work by Stoelinga and Leenen (1981) did not support Isaacson's proposal and found that if no intraosseous wiring was used, relapse would be unacceptably high.

Hall (1991) advocates minimal stripping of the medial pterygoid muscles as he believes this will help to seat the condyles if no rigid fixation is used. Epker et al. (1978) and Worms et al. (1974) suggested that surgical wafers be designed to open posterior occlusion in anticipation of future reseating of the condyles.

Kundert and Hadjianghelou (1980) examined 35 patients who underwent bilateral sagittal split osteotomies and used radiographs to assess condylar position. From their results they made the following conclusions:

(1) Condylar displacement was frequently found after sagittal splits.

(2) Displacement combined with rotation or tilting of the condylar long axis predominate.

(3) Type of osteosynthesis and direction of movement of the distal fragment seem to influence direction and amount of condylar displacement.

Leonard et al. (1985) describe a proximal segment orienting device which helps to ensure that the condyles are seated prior to rigid fixation. As mentioned previously Van Sickels et al (1990) take this idea one step further and advocate placement of a condylar positioning plate from the maxilla to the proximal fragment. Mertens and Halling (1992) believe that a mini plate is not rigid enough and suggest a technique where they inject autopolymerizing acrylic resin into a silicone tube placed over the mini plate, used as a condylar positioning device. Clearly if one is using a condylar positioning device then one needs an accurate record of centric relation. Much controversy surrounds the best way of recording this. Hase (1988) describes a technique where the patient bites into a device known as a leaf gauge as the bite record is taken. He reported that this records a reproducible seated condylar position.

Smith et al. (1991) cite unfavourable splits as a troublesome complication during surgery and advise placing the medial horizontal cut at or just above the tip of the lingula in order to minimize this complication. Mommaerts (1992) also reports two cases of bad splits and describes how they were corrected using a modification of the "Obwegeser II" technique and screw osteosynthesis. Van de Perre et al (1996) in a retrospective study of 1233 patients who underwent bilateral sagittal split osteotomies between 1974 and 1995, reported unfavourable splits occurred in 7.8% of patients. In most instances these were repaired by placement of an extra plate to the osteotomy site and did not require postoperative IMF.

Reubens (1988) reporting on a series of twenty patients having mandibular advancement using the bilateral sagittal split method found that four patients suffered unilateral buccal plate fractures, he noted that these patients exhibited more than average relapse.

2.7.3 Immediate post operative complications

Van de Perre et al. (1996) in a study which included 1886 patients who had mandibular osteotomies stated that immediate life threatening complications were very rare. They however reported a 17 year old patient who died from a cardiac arrest six hours following mandibular advancement surgery. No autopsy was performed, and it was speculated that he died from an undiagnosed pre existing cardiomyopathy. In the same study they also reported two patients who required urgent tracheostomy due to excessive swelling in the floor of the mouth following sub apical osteotomy in the mandible.

Martis (1984) examined 258 cases where the bilateral sagittal split was used to correct both mandibular deficiency and mandibular excess, and noted several early post operative complications. Postoperative bleeding requiring further surgery (incidence 0.4%), severe oedema (1.6%), bilateral inferior alveolar nerve paraesthesia (72.9%) and unilateral inferior alveolar nerve paraesthesia (6.6%). By twelve months 96.2% of the patients had regained full sensation over the distribution of their inferior alveolar nerves, spontaneously. Facial nerve paralysis occurred with an incidence of 0.4% but resolved spontaneously.

There are few cases of post operative infection in the literature, Wang et al (1975) reported a series of 32 patients who had mandibular osteotomies performed, where two developed pyrexia which lasted for two days and resolved. They did not verify that this was due to infection. Hogevold (1991) reported several infections following mandibular orthognathic surgery with the result that they now routinely use prophylactic antibiotics. Nordin et al (1987) reported three cases out of a series of twenty who had extraoral mandibular osteotomies performed who developed post operative infections requiring antibiotics. Van de Perre et al (1996) used antimicrobial prophylaxis of intravenous penicillin or erythromycin for varying periods ranging from one to five days, they found an infection rate of 8 out of 2049 cases of orthognathic surgery requiring incision and drainage.

Tornes (1987) reviewed and compared the perioperative and postoperative complications between the intraoral and the extraoral technique of the vertical sub sigmoid osteotomy of the mandible. Both techniques were considered to be safe and satisfactory, however the extraoral approach was favoured because it resulted in less operative time, blood loss and swelling, and a significantly shorter stay in hospital. It does however result in a skin scar which may be unaesthetic.

2.7.4 Delayed postoperative complications

Perhaps the most widely published delayed postoperative complication are nerve injury and relapse, these will be discussed in detail in Chapters 7 and 4 respectively .

Other reported complications include:

(a) Temperomandibular joint (TMJ) dysfunction
(b) Non union of bony fragments
(c) Condylar resorption
(d) Trismus

TMJ Dysfunction

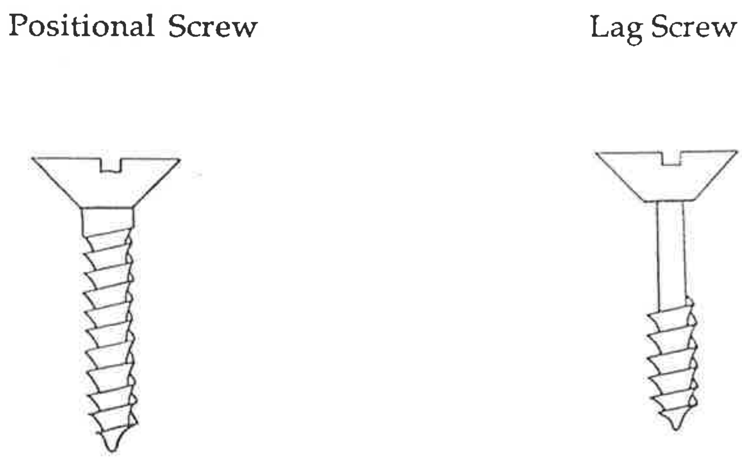
There are few reports of the incidence of TMJ problems following mandibular advancement, however there is currently much interest in TMJ pathology in general and undoubtedly this is an area where further research will occur. A study is currently underway in the Oral and Maxillofacial Surgery Unit, The University of Adelaide.

Timmis et al. (1986) observed an improvement in temporomandibular joint pain as well as a decrease in the incidence of TMJ clicking in 14 patients treated with three screw rigid internal fixation when compared to 14 others treated with conventional wire fixation and IMF for six weeks.

McDonald et al. (1987) noted that in a series of 22 patients who underwent mandibular advancement using the bilateral sagittal split osteotomy, no patients experienced TMJ pain postoperatively. One patient experienced pain preoperatively but this resolved following surgery. No patients had clicking preoperatively whereas four patients were found to exhibit postoperative clicking. The authors however note that further long term studies beyond the six month period are needed to confirm their results.

Compressive techniques may give rise to TMJ arthropathy according to Martis (1984), Leonard et al (1985), and Lindorf (1986). Compressive techniques involve fixation of the fragments using compression lag screws which are designed to put the fragments under compression. The alternative technique is to use non compression bicortical or positional screws, which should minimize torque on the condyles. (Figure 2.12). McDonald et al (1987) reported the use of Champy plates adapted to the buccal cortical plate across the osteotomy site with the proximal segment in a passive position. The authors believed this resulted in minimal torquing of the proximal segment.

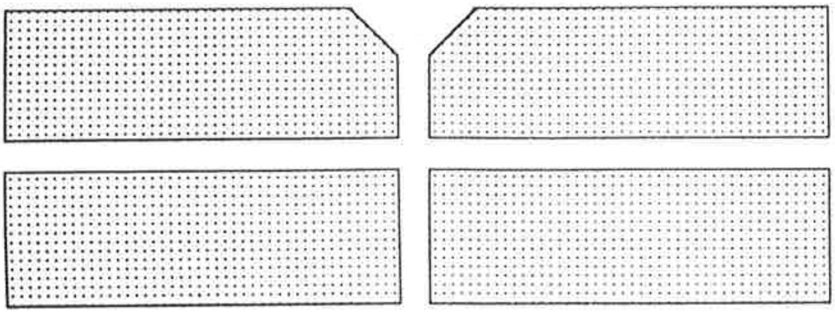
Figure 2.12 The design of positional and lag screws



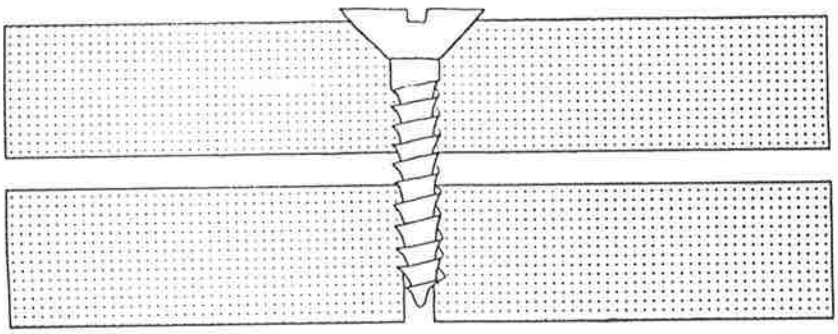
With the use of a positional screw, as the name implies, the relationship between the proximal and distal fragments are maintained, whereas when a lag screw is tightened the two fragments are drawn together. (Figure 2.13)

Several authors have looked at T.M.J. function following mandibular setback procedures. Boyne (1966) performed vertical subsigmoid osteotomies on Macaca resus monkeys. Prior to sacrificing them, he administered tetracycline at various points in time, which when viewed under ultravoilet light fluoresces. This enabled him to see areas of new bone deposition. He found that in

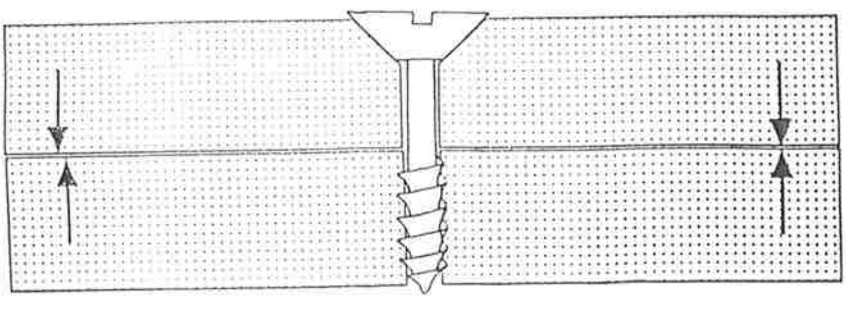
Figure 2.13 The effect of using positional or lag screws



Positional screw



Lag screw



addition to bone being formed around the osteotomy site it was formed at the attachment of the lateral pterygoid muscle and there was peripheral remodelling of the condylar head.

Edlund et al (1979) performed a follow up study of 44 patients that had undergone mandibular setback using bilateral sagittal splits, they noted a significant decrease in protrusive movement of the mandible. The activity of the temporal muscle in the rest position was also found to have decreased post surgically. Radiographs taken one to two years postoperatively showed the formation of a double contour of the posterosuperior margin of the condyle in almost 50% of the cases. They speculate that condylar distraction may serve as a stimulus for condylar remodelling causing the appearance of the double contour on the radiograph.

Trismus

Hogeman (1951) found a decrease in maximum mouth opening of about 4 mm following horizontal osteotomy of the mandible. Edlund et al (1979) noted a decrease in maximum opening capacity of approximately 10 mm one to three years post operative in a series of patients who underwent bilateral sagittal split osteotomies, they also noted bony changes to the condylar head. Similarly McDonald et al (1987) in a sample of 22 patients who underwent mandibular advancement with bilateral sagittal split osteotomies and a period of IMF for six weeks found that maximal opening was reduced by an average of 4 mm at six months post operative compared to the preoperative value, likewise lateral excursions were reduced by about 30%.

This is in contrast to Throckmorton et al (1995), who found no long term decrease either in maximum opening or lateral excursions following mandibular advancement in a series of 24 patients. The patients, all female, were found to have hypomobility at six weeks but by one to two years normal function had returned.

Aragon et al (1987) demonstrated that early release of IMF combined with mild physiotherapy improved maximal interincisal opening following mandibular surgery.

Goss (1979) showed that there was no long term reduction in mouth opening in patients following prolonged IMF for the treatment of weight loss. However the situation may be different in surgical patients where scarring may occur in the absence of movement.

Condylar resorption following mandibular advancement

Worms et al (1980) first suggested condylar resorption (condylysis) as a contributing factor to relapse, they noted that it was observed most commonly in advancements which rotate the mandible in a counter clockwise direction.

Huang and Ross (1982) observed condylar resorption in growing children following mandibular advancement procedures. In cases where the advancement was greater than 10 mm resorption was noted in more than half the patients. Sesenna (1985) reports of a patient undergoing bilateral condylar resorption following mandibular advancement and Kerstens et al (1989) also described an incidence of condylar resorption of 5.5% in a study of 206 patients who underwent mandibular advancements.

Moore et al (1991) reported five cases of condylar resorption in patients who had mandibular advancement. Their findings suggest a potential target group of patients that may be predisposed to condylar resorption. They defined the target group as follows:

(1) Female.

(2) Age 20 to 30 years.

(3) Presence of a preoperative high mandibular plane angle.

(4) Presence of preoperative TMJ dysfunction.

(5) Cases with large mandibular advancements.

(6) Cases with proximal fragment counterclockwise rotation.

2.7.5 Complications associated with the extraoral approach

(a) Scar formation

Nordin et al (1987) state that the extraoral scar associated with an extraoral approach may be an indication for performing an intraoral approach. Reitzik (1988) also states that the scar associated with the extraoral route is a disadvantage, but adds that the degree of patient acceptance is excellent if the incision is placed in a natural skin crease. Clearly, when aesthetics is a high priority, the extraoral approach is contraindicated.

(b) Problems in assessing the level of the lingula

When performing an inverted "L" osteotomy via the extraoral approach, difficulty is encountered in assessing the position of the lingula. Yates et al (1976) have shown that the antilingula is an unreliable guide to the level of the lingula. To avoid damage to the inferior alveolar nerve and vessels when performing the horizontal cut it may be wise to use either the method described by Reitzik (1976) or the Trauner and Obwegeser (1957). Reitzik advocates placing the intersection of the horizontal and vertical cuts a point 8 mm above and 11 mm behind the midpoint if the waist of the ascending ramus. Trauner and Obwegeser (1957) described a method, where the horizontal cut is made via an intraoral approach. The latter method has the disadvantage of creating a 'through and through' wound thus contaminating the extraoral incision with oral organisms.

(c) Damage to the facial nerve

Hensel (1937) noted the danger to the facial nerve from extraoral osteotomies. Hogeman (1951) reviewed 171 cases where the mandible was set back using a sliding osteotomy of the ramus (extraoral) two to eighteen years post operatively and he found facial nerve damage in 38% of cases.

Piecuch and Lewis (1982) report a case of a full unilateral facial nerve paralysis, caused by performing a bilateral sagittal split osteotomy advancement in a male patient, which returned to normal after about three months. They reported that this followed an unfavourable split of the proximal fragment on the affected side. Damage to the marginal mandibular branch of the facial nerve is a well known complication of extraoral approaches to the mandibular ramus according to Jones and Van Sickels (1991). They go on to report that there is an extremely low incidence of permanent deficits indicating that the majority of injuries are due to blunt trauma during flap retraction. They point out that intraoral procedures carry only small risk of damage to the nerve and in these cases the mechanism of injury is thought to be blunt trauma secondary to the placement of retractors posterior to the ramus. They report that at the time of publication all of the reported injuries with the intraoral procedures spontaneously resolved after a variable length of time.

Dattilo et al (1985) describe an approach to the mandibular ramus via the extraoral route and emphasise the importance of attempting to identify the marginal mandibular branch of the facial nerve, and when encountered, dissecting and retracting it out of the operating field.

De Vries et al (1993) report on a series of 1747 sagittal split osteotomies performed in several different centres in the Netherlands from 1986 to 1990, they found nine cases of facial nerve injury (0.26%). Of these, 6 were mandibular advancement procedures and 3 were set back procedures. After one year, three of the patients showed incomplete recovery.

There are no reported cases of facial nerve weakness following an inverted 'L' osteotomy. Perhaps because it is a relatively uncommon procedure. Both the intra and extraoral inverted 'L' osteotomies do pose a potential risk to the branches of the facial nerve. The extraoral approach because of the position of the incisions relative to the marginal mandibular branch, and the intraoral because it involves stripping around the posterior border of the mandible.

(d) Parotid fistula

Parotid fistula formation following mandibular orthognathic surgery is a very rare event. Goldberg and Googel (1973) report a case of a parotid fistula developing after a patient underwent a vertical subsigmoid osteotomy for correction of mandibular prognathism, via the extraoral route. Despite careful closure of the tissues in layers, the patient developed a parotid fistula on the sixth post operative day, which resolved spontaneously approximately two weeks later. The authors note that the most common cause of salivary fistula is sharp trauma to Stensons duct, clearly this would be a rare event from an incision placed in the usual position for access to the mandibular ramus. Anderson and Byars (1965) note that it is rare to get formation of salivary fistulae following surgery to the parotid gland.

CHAPTER 3

CEPHALOMETRY

3.1 INTRODUCTION

The first X ray pictures of the skull in the standard lateral view were taken by Pacinci and Carrera (1922) according to Rakosi (1982). In subsequent years, the following authors also produced this type of radiograph for the evaluation of craniofacial measurements: MacGowan (1923), Simpson (1923), Comte (1927) , Reisner (1929), and others (from Rakosi (1982)). None of these researchers gave an accurate description of the methods used to take the radiographs, thus one cannot directly compare the results of different studies. It was not until 1931 that Broadbent developed standardised methods for the production of cephalometric radiographs, using a special holder known as a cephalostat, to permit assessment of growth and of treatment response. The science of ceplalometrics was thus born.

Cephalometrics gained popularity, initially as a research tool and then in orthodontics in the 1960's as a clinical tool. Moyers and Brookstein (1979) describe how cephalometrics can be used to study craniofacial growth, to diagnose deviation of an individual from population norms, and to plan orthodontic treatment and assess its progress and results. With the advent of the increasing popularity of orthognathic surgery it was obvious that it would find uses in this area and Brodie (1955) demonstrated that it is a valid tool for monitoring the effects of such surgery. Cephalometrics is a complex science involving the overlap of many disciplines such as radiography, radiology, biostatistics and may require complex computers for data storage and analysis in addition to the clinician's skill. Moyers and Bookstein emphasise that there is no theory of cephalometry, but only conventions. According to Houston (1983) if any study using measurements is to be of value, it is imperative that error analysis be undertaken and reported.

Many sources of errors associated with cephalometrics have been described in the literature, Midtgard et al (1974), Martinoni (1978), Houston (1983) and Seppo (1987). Various methods have been employed to help minimise error Broadbent (1931), Hurst (1978).

Houston (1983) divides errors associated with cephalometry into systemic and random errors. If a particular measurement is persistently over- or under recorded, a systemic error is introduced. He gives an example of a systemic error where measurements from study models are compared to measurements from a radiograph without allowances for radiographic enlargement. Random errors occur as a result of human error and Houston concludes that the greatest source of random error is difficulty in identifying a landmark or imprecision in its definition.

Houston et al (1986) describe how the conventional process of recording data from lateral cephalograms involves three stages: obtaining the radiograph; landmark identification and measurement.

Ching (1995) expands these stages further, namely:

- (i) taking of the lateral head radiograph;
- (ii) tracing the cephalogram;
- (iii) identification of landmarks;
- (iv) recording the observation; and
- (v) measuring the observation.

Errors can occur in all these stages and so errors can be classified according to Hing (1989) as;

(i) errors of projection;

(ii) errors of landmark identification;

(iii) errors of superimposition;

(iv) errors of digitising;

(v) errors of measurement; and

(vi) errors attributable to operator variability.

3.2 ERRORS OF PROJECTION

Since the inception of cephalometry researchers have been aware of the limitations of projecting a three dimensional object onto two dimensional film, and have discussed ways of minimising these errors. Baumrind and Frantz (1971a) summed up the situation well by describing lateral cephalograms as *distorted enlargements*. Most authors agree that while these errors are significant, they are usually considered to be less important than other errors. (Hatton and Grainger, 1958; Savara et al., 1966; Carlson, 1967; Baumrind and Frantz, 1971b; Ahlqvist et al, 1986)

Krogman (1958) noted that mid sagittal measurements are preferable for they involve only two planes in space. Van Aken (1963) reiterated this, but also observed that projection errors might be of significance in cephalographs of asymmetrical skulls. Bergersen (1980) investigated magnification and distortion in cephalometrics and found differences between distances measured on the film and true distances in the object. Compensation tables were then constructed for correcting linear measurements.

Eliasson et al (1982) presented the basic mathematics for calculating projection errors, enabling one to calculate the position of any landmark on the film for any misalignment between the components of the cephalographic system.

Ahliqvist et al (1986) summarise the theoretical principles involved in the production of projection errors. They note that the focal spot may be considered a point source from which the x-ray beam diverges. Ideally the film plane is perpendicular to central ray of the beam. For a lateral cephalogram the sagittal plane of the patient should be perpendicular to the central ray of the beam. In practice however they report that there are three ways that the cephalographic system may vary from the ideal:

1. the focal spot, the cephalostat, and the film may be linearly displaced relative to each other;
2. the cephalostat and the film may be rotated with respect to each other;
3. the patient may be linearly displaced and /or rotated in relation to the cephalographic system.

Ahlqvist et al. further investigated the effects of projection errors on linear measurements and concluded that rotation of the head about either a vertical or horizontal axis plus or minus 5 degrees from the ideal, usually results in errors that are less than one percent. With regard to focus to object distances they note that while short distances result in greater projection errors, their results indicate that there is little gain in using extremely long distances. Ghafari et al. (1995) confirmed Ahlqvist et al's findings that transverse measurements were not significantly affected by a head angulation ± 5° from the ideal.

3.3 ERRORS OF LANDMARK IDENTIFICATION

Many studies have been published on errors associated with landmark identification, these include: (Bjork, 1947; Hatton and Grainger, 1958; Miller et al. 1966; Savara et al.1966; Carlsson 1967; Brown et al. 1970; Midtgard et al. 1974; Broch et al. 1981; Houston, 1983; Chate, 1987; Vincent and West, 1987; Tng et al., 1994). Most authors agree that landmark identification is the main source of error, in fact Broch et al go as far as to say that if a digitiser is used, it is the *only* source of error.

Broch et al. (1981) investigated the error in landmark identification for 15 landmarks. This was done by digitising 30 lateral cephalograms, with the X axis being aligned to the NS line, then one month later the cephalograms were rerecorded and the results compared. Using their technique the error of superimposition was so small that they considered, in practical terms, discrepancies may be attributed to variations in landmark identification. The differences between the two recordings were plotted on an X and Y axis, it was found that the method error varied from landmark to landmark, for example the X coordinates for incision inferious varied by a maximum of 0.4 mm whereas for Basion they varied by 3.6 mm. Another finding was that the deviations between recordings are spread along the axis in different ways for different recordings. Broch et al's work supports the findings of Richardson (1966) , Baumrind and Frantz (1971a).

Baumrind and Frantz (1971a) found the identification of porion to have a high reliability, however they used machine porion that is based on the position of the ear rod. Rickets (1981) notes that the ear rod has been noted to be located well over 1 cm from the true porion.

Broch et al (1981) state that the reliability of landmark identification depends on the following factors:

(i) characteristics of the cranial structures;
(ii) the general quality of the headplate;
(iii) blurring of the anatomical structures caused by secondary radiation or movement during exposure;
(iv) precision of the recording method; and
(v) accuracy of the operator.

Baumrind and Frantz (1971b) report that many landmarks involve estimating the position of a point on an edge. Where the edge folds sharply such as the upper incisor edge, the estimates are very good, however where the edge is a gradual curve such as A point and B point, the task is more difficult and the errors are larger and are distributed along the edge itself.

Baumrind and Frantz (1971a) and Vincent and West (1987) report that it is easier to identify a landmark in an area of high contrast. They also report that landmark identification is made difficult in those areas where superimposition of other structures interferes with clarity, for example landmarks located around the region of the condylar head.

Another problem with landmark identification is vague definitions, Baumrind and Frantz (1971b) used the example of Gonion; this was defined as the point where the ramus and body of the mandible meet, this was found to be subject to too much inter observer differences. Other authors, Houston (1983), Savage et al. (1987), agree that more precise landmark definitions should be adopted but the problem is to get universal acceptance.

Moyers and Bookstein (1979) divide landmarks into those which they classify as 'anatomic' and those which are 'extremal'. Anatomic landmarks are true biologic loci, identified by some feature of the local morphology, whereas extremal points are defined by the maximum or minimum of some geometric property. They point out that if extremal points are used say for example in the mandible, as the mandible rotates the position of all extremal points on it are altered. Such rotation may be a relative rotation , that is failure to orientate the cephalogram correctly or in longitudinal studies may be due to growth or surgery. Jarvinen (1987) demonstrated that jaw closure increased variability by rotating the mandible into a different position.

Gravely and Murray-Benzies (1974) suggest reducing random errors in landmark identification by digitising each cephalogram more than once, a view also held by Houston (1983). Baumrind and Miller (1980) suggested digitising the cephalogram on four separate occasions.

Eriksen and Solow (1991) stress that error in landmark identification can be reduced by high image quality of the radiographic films. Gravely and Murray Benzies (1974) felt that image quality was not so important, they noted that clarity often varies between one anatomical site and another on the same film. Hurst et al (1978) compared landmark identification using xeroradiographic cephalograms and conventional cephalograms. Identification accuracy of fourteen landmarks was compared. Four landmarks -- point A, upper incisor tip, infradentale, and menton -- were more accurately determined on the xeroradiograph, while two landmarks -- point B and condylion, were more accurately determined on conventional cephalogram. Radiation exposure with Xerograms was significantly greater than conventional cephalograms and accordingly their use has been discontinued in most centres.

Because the position of the landmarks can be affected by, growth, orthodontics and surgery, Bjork (1968) used markers made from tantalum wire to investigate growth in children. Reitzik (1980) highlights the need for fixed bone markers for accurate cephalometric tracing near osteotomy sites. Today, with more emphasis on ethics for experiments, it is much harder to justify the placement of markers for research.

3.4 ERRORS OF SUPERIMPOSITION

Much has been written on errors associated with superimposition. It can be confusing since there are two applications in cephalometry where superimposition is used, and often the literature is ambiguous. The first application is where multiple tracings are made from a master cephalogram and the tracings then analysed to assess the error of landmark identification, these include the above mentioned studies by Baumrind and Frantz (1971a), Broch (1981) and Vincent and West (1987). The methods used to register the tracings to the radiograph have included marking points, pin pricks or punching holes and then using pins to register the position. Broch (1981) investigated the error associated with superimposition of tracings on cephalograms, this was done by measuring the difference between two registrations of the SN line relative to a third random point. They used a digitiser and found the error to be 0.03 mm in both the X and Y directions.

The second application of superimposition is in longitudinal studies where lateral cephalograms taken of an individual at different points in time are superimposed for comparison. Usually the radiographs are superimposed by aligning an anatomic plane, usually part of the anterior cranial base.

Bjork (1963) was one of the first to describe how cephalograms could be superimposed by sliding one over the other until the best fit of cranial base anatomy is achieved. Kerr (1978) describes the Adams Blink Comparator, a device which produces a virtual superimposition by looking through a viewer at two films placed side by side. He did not report the error of the method and the device did not gain widespread acceptance.

Houston and Lee in 1985 compared five different methods of superimposition: (1) direct superimposition of cephalograms; (2) the Adams Blink comparator; (3) subtraction. They cite the work by Lee (1980) who describes the subtraction method of superimposition. In this method a positive copy of one of the films is made and superimposed over the other film, structures that match perfectly appear uniformly grey; (4) registration of tracings of the cranial base; (5) tracings on the SN line registered at sella. They found that appreciable errors were associated with each method of superimposition, but these did not differ significantly between methods. The trend was for superimposition on the SN line to give the lowest error, however they caution that with growth nasion may drift vertically. They concluded that as no one method of superimposition of cranial base structures was outstandingly better than any other, then the choice of method should be based on cost and convenience.

Baumrind et al (1976) investigated errors associated with superimposition and divided them into primary and secondary errors. Primary errors are due to the land marks in question not being correctly aligned, hence there being rotational and/or translational error. Secondary errors are the effect of the primary error on distant landmarks. They give an example of a point lying 100 mm from a centre of rotation being displaced 1.74 mm by a rotation of 1°.

It is important to note that superimposition is not the only way of comparing cephalograms taken at different times, Baumrind et al (1976) report that the other method which can be used is the individual film method. With this method each film is evaluated individually by making the same set of measurements on tracings of each film in the series. Then the measures values from one tracing are subtracted from those of other tracings, and the differences in value are taken as a measure of between-timepoint changes. They note that the individual film method and the superimpositional method are not mutually exclusive and thus both methods can used in conjunction.

3.5 ERRORS OF DIGITISING

Digitisers linked to computers for analysis of cephalograms have been available for research purposes since the late 1960's however these early machines were costly and cumbersome. (Barrett et al., 1968) With the advent of less costly machines the analysis of cephalograms has been made easier, faster and more accurate. (Cohen, 1986) Most dental schools and many Oral and Maxillofacial surgeons and Orthodontists in private practice now possess digitisers. It has been shown by Bergin et al. (1978), Richardson (1981) and Broch et al. (1981) that digitising is more accurate than measuring distances manually.

Houston (1979) discusses resolution and accuracy of digitisers, resolution being the shortest distance which can be distinguished between two points and accuracy being the error of measurement of a line of given length. He states that a digitiser should have an absolute accuracy of better than 0.15 mm, provided this is the case it should not contribute appreciably to the error with which points are recorded.

Eriksen and Solow (1991) investigated the linearity of digitisers, they found that with regard to the X axis deviations were approximately within ± 0.1 mm range, however they noted that most digitising systems are not linear. This means that a given line segment will be recorded as having different lengths depending on where it is placed on the digitising surface. To improve accuracy they advise checking the function of the digitiser with a calibration grid. All researchers agree that the errors associated with digitisers are small in relation to those associated with landmark identification.

3.6 ERRORS OF MEASUREMENT

Krogman (1958) states there are three basic types of cephalometric analysis: linear, angular and positional. Linear is dimensional and is measured in millimetres, angular is relational and is measured in degrees, positional is patterning and Krogman feels this is more in the realm of qualification. Clearly in measuring distances and angles errors will occur. We have previously shown in section 3.3 that most consider landmark identification is by far the main source of error. Gravely and Murray-Benzies (1974) report that measurement error associated with the thickness of the pencil line and the perceptive limit of the human eye also contribute to tracing error. For this reason some have advocated digitising directly from the radiograph. (Broch et al., 1981 and Bondevik et al., 1981) Houston (1982) noted that this method is less tedious. Others believe that tracing the radiograph and then digitising from the tracing contributes only insignificantly to the overall error.

Bjork (1947) includes mechanical errors involved in the use of protractors, rulers and line drawing. Bondvik et al (1981) demonstrated that errors associated with digitising selected points was less than 0.1 mm, about one fifth that of the error associated with the manual process.

3.7 ERRORS OF OPERATOR VARIABILITY

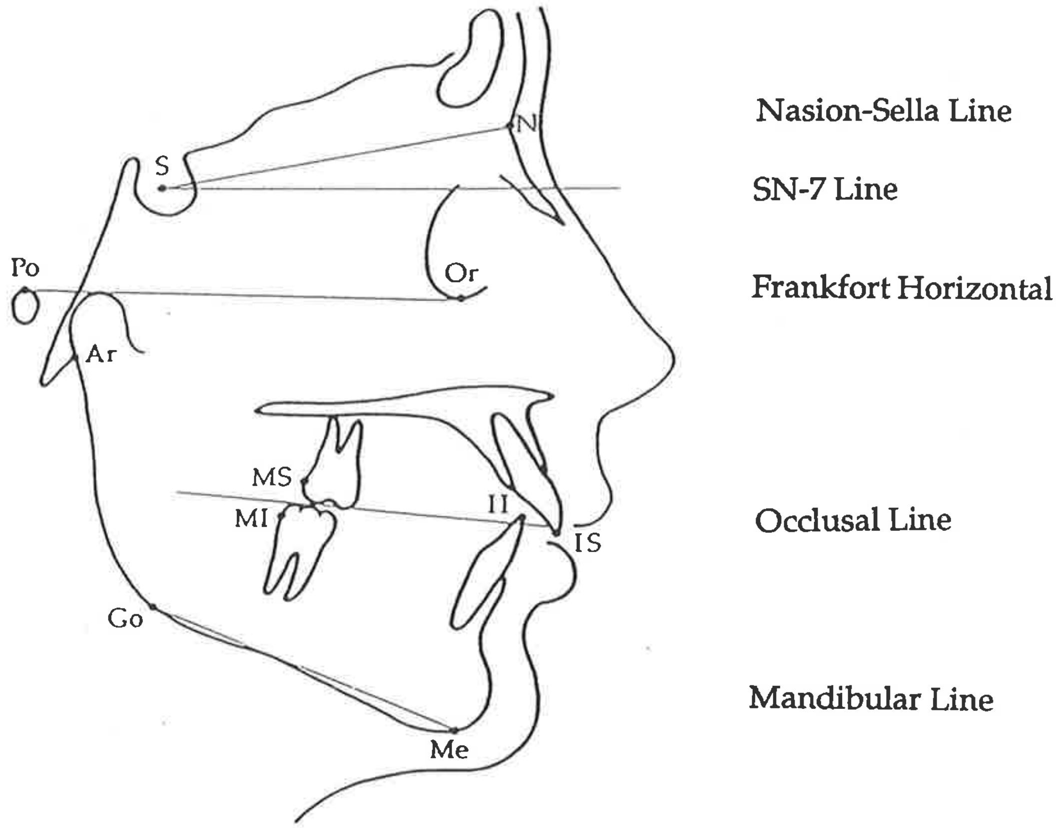
Different operators may interpret landmark definitions differently and may have different techniques of measurement and this may be a source of error, thus, where possible, for a study a single operator should trace and digitise all the radiographs. (Savage et al., 1987)

3.8 THE SELECTION OF A SUITABLE REFERENCE LINE

Broadbent (1937) was the first to describe superimposing longitudinal cephalogaphs on planes representing the cranial base for studies of growth. Since then many similar studies have been undertaken. Bjork (1963) demonstrated that certain internal structures of the mandible remained stable with time. Accordingly others have continued investigating superimposition of mandibular structures, mainly for clinical studies. (Skieller, 1967; Mills, 1973; Cook & Gravely, 1988) Mandibular surgery makes mandibular superimposition difficult and hence most authors have superimposed cranial base structures for cephalometric studies involving mandibular surgery.

Hing (1989) provided a comprehensive review of the literature and concluded that whilst no single line of reference fulfils the ideal criteria, the nasion-sella line was the most appropriate due to its low error method and its ease of location. Various reference lines have been investigated, these include; the Frankfurt horizontal, Nasion-Sella line and the SN-7 line. (Figure 3.1).

Figure 3.1 Reference lines referred to in the text after Hing (1989)



CHAPTER 4

SKELETAL RELAPSE FOLLOWING MANDIBULAR ADVANCEMENT SURGERY

4.1 INTRODUCTION

The most troublesome complication of mandibular advancement procedures is skeletal relapse according to McDonald et al (1987). Investigators have shown consistently that the surgical changes are not entirely stable, nor is the degree of stability routinely predictable. (Lake et al., 1981; Will et al., 1989; Mommaerts et al., 1990) Indeed the average amount of skeletal relapse from a series can be as high as 77% of the initial correction. (Sandor et al.,1984)

It is generally considered that relapse is more of a problem with mandibular advancements than with setbacks. (Poulton & Ware, 1971; Farrell & Kent, 1977) It is thought that the reason for this is twofold; first by advancing the mandible the soft tissues are stretched creating tension on the skeletal elements, second, with mandibular deficiency, the mandible is hypoplastic and hence when the mandible is advanced there is likely to be less bone in contact across the osteotomy site.

4.2 DEFINING POST SURGICAL RELAPSE

Although much has been written concerning relapse, no unified definition exists. Reitzik (1988) states that the word relapse is commonly understood to denote a return to the preoperative state. Hing (1989) notes that Reitzik's broader definition encompasses skeletal and occlusal changes, accordingly, this broader definition will be used throughout this study.

Reitzik's definition implies that for mandibular advancement surgery relapse will be directed posteriorly, however this is not always the case. Kierl et al. (1990) studied relapse in a sample of 19 individuals who underwent mandibular advancement surgery with a bilateral sagittal split osteotomy, and found that five of the subjects moved further forward, one advancing more than 50% more than the original advancement.

At first the concept of relapse may be hard to grasp as one would expect bone being a rigid material, to stay where it is put. However this is a gross simplification as bone is a biologically dynamic material. There are various explanations of what happens to produce relapse, but clearly this is a multifactorial process. The literature concerning relapse is often ambiguous and confusing. Reitzik (1980) tried to explain relapse as consisting of two separate entities. "Immediate relapse" occurred during the period of IMF and immediately upon release of fixation. Reitzik attributed this type of relapse to be due to repositioning of the condyle in its physiologically neutral position within the fossa, and also movement between the fragments at the osteotomy sites if they are not rigidly fixed. The second type of relapse that he believed occurred was what he called "long term relapse", this he considered happened after release of fixation. He believed this was due to change in the relationship of the fragments at the osteotomy sites. It would seem likely that a third type of relapse due to remodelling of the entire mandible would be possible.

4.3 MEASUREMENT OF POSTSURGICAL RELAPSE

No ideal method has been devised for measuring post surgical relapse, probably because there are so many variables and so many factors that may mask or be mistaken for relapse. Broadly speaking, researchers have, in the past, looked at either occlusal changes or skeletal changes measured from radiographs (cephalometrics) to assess relapse.

There is also no universally accepted method of measuring or reporting post surgical relapse. Some researchers have reported a figure as being average relapse for a sample. This is sometimes expressed as a linear measurement and sometimes as a percentage of the average advancement. As Kierl (1990) noted, relapse can potentially occur in either direction so the commonly used method of reporting average relapse can be misleading. Thus, it is often hard to compare the results of different studies.

Other studies quote the number of patients within a sample who experienced relapse. (McDonald et al.,1987) Gassman et al. (1990) divided patients who had mandibular advancements using bilateral sagittal split osteotomies into two groups, those which experienced relapse and those that did not. They reported that this enabled them to make stronger statements regarding the contributing factors of relapse.

Burstone (1978) describes a cephalometric analysis specifically for use in orthognathic surgery. Its use is threefold; as an aid in diagnosis, as a tool for simulating surgery, and to evaluate surgical changes. In cephalometrics researchers have investigated a variety of landmarks, including markers implanted at the time of surgery.

With the advent of safe procedures to advance the mandible it was not long until the occurrence of relapse was noted. Poulton and Ware (1971) were among the first to report on relapse when they noted that skeletal relapse was possible during IMF. They speculated that relapse was caused by excessive suprahyoid muscle tension.

Behrman (1972) reports on relapse following sagittal osteotomy of the mandibular ramus and McNeill et al. (1973) presents four cases of skeletal relapse following mandibular advancement surgery. They describe a technique where cephalometrics is used to compare serial radiographs using several dental and skeletal landmarks. Other researchers, mostly from North America, have also advocated assessing relapse using cephalometrics these include: Ive et al. (1977), Farrell et al. (1977), Poulton et al. (1979), Reitzik (1980), Lake et al. (1981), Dattilo et al. (1985).

European studies have, in the past, looked at the occlusion to assess relapse. (Freihofer & Petresevic, 1975; Macintosh, 1981; Lello, 1987) MacIntosh (1981) also included a study of occlusal casts in conjunction with cephalometric soft tissue profile to assess relapse but however found that this method was unsatisfactory due to its complexity .

Worms et al. (1980) report that they regularly use longitudinal laminagraphic X rays of the condyles, cephalometric radiographs and occasionally used implanted markers to assess relapse. Rosenquist et al. (1986) also reports using implanted markers to assess relapse.

Cephalometrics has become the most widely accepted method of assessing relapse although no standard system of landmarks has been universally accepted.

Ayoub et al. (1993) report on the use of finite element analysis for the evaluation of stability following genioplasty. Finite element analysis is a system of mathematical modelling best known for its application in engineering. The authors report that this method of analysis is capable of separating changes due to repositioning from those of remodelling. They define repositioning as failure of a bone segment to maintain its position in relation to adjacent bones, whereas remodelling is a combination of bone resorption and apposition causing shape changes rather than positional changes. Generally the mathematics involved in finite element analysis are extremely complex, however Sameshima and Melnick (1995) describe a computer program which greatly simplifies the concept for use in cephalometric analysis.

4.4 EARLY, INTERMEDIATE AND LONG TERM RELAPSE

As well as quantifying relapse, it is important to establish when the relapse is occurring. By knowing when relapse is occurring one may be able then to devise ways of reducing it.

At The University of Adelaide, Hing (1989) adopted the following chronological sequence;

Early relapse	0-2 months
Intermediate relapse	2-12 months
Long term relapse	greater than 12 months

The main reason for defining early relapse as 0-2 months was that originally all patients were placed into IMF for a period usually less than two months, thus early relapse consisted of changes that occurred during IMF or upon release of IMF.

4.5 STABILITY OF THE BILATERAL SAGITTAL SPLIT OSTEOTOMY

There are a great many studies looking at the stability of the bilateral sagittal split osteotomy for mandibular advancement over varying time periods, some selected studies are included in Table 4.1.

Most studies looking at relapse suggest that most relapse occurs during the short term. (McNeil et al., 1973; Schendel & Epker, 1980; Gassman et al., 1990) In fact McNeil and other authors showed that skeletal relapse occurred during IMF. Upon release of intermaxillary fixation further relapse occurred due to failure to seat the condyles at the time of surgery. With rigid fixation it seems that most relapse also occurs early. (Van Sickels & Flanery, 1985)

4.6 STABILITY OF INVERTED 'L' OSTEOTOMY

Farrell and Kent (1977) assessed the stability of twenty patients who had mandibular osteotomies, using inverted 'L' osteotomies for ten cases and 'C' osteotomies for the other 10 cases. The inverted 'L' procedure was used where the posterior facial height needed to be increased, seven of this group had preoperative anterior open bites. Three of these seven had setback procedures and two had mandibular advancements. Of the remaining three inverted 'L' group, two patients exhibited mandibular prognathism and one bimaxillary prognathism. Eight of the inverted 'L' procedures were carried out via an extraoral approach and two via the intraoral route (the intraoral cases were for setbacks). Their results are reported as percentage relapse of the original advancement and as such not state the range.

The 'C' osteotomy was selected in cases where advancement of the mandible was required. Four of the ten patients had additional deformities that required

Table 4.1 Selected studies of relapse associated with the B.S.S.O. for advancement

Author	Year	Patients	Time	Method*	%Relapse
Poulton et al.	1971	3	6m	UBW	23-44
Poulton et al.	1973	8	9-43m	UBW	10-30
Ive et al.	1977	21	med	UBW	30
Kohn	1978	17	>6m	UBW	49
Freihofer et al.	1978	118	long	UBW	10-60
Isaacson et al.	1978	3	9-12	IMF only	43
Poulton et al	1979	20	24m	UBW	47.5
Wessberg et al	1982	5	short	Wire + myotomy	46
Lake et al.	1981	52	long term	UBW +soft collar	19
Sandor et al	1984	20	short	UBW	10
Will et al	1984	41	short	UBW+ soft collar	45
Van Sickels et al	1985	9	6m	bicortical screws	minimal
Hardy &Piecuch	1985			wire	45.8
Kirkpatrick et al	1987	20	6m	bicortical screws	8
Ellis & Gallo	1986	20	2m	Wire + skel. suspension	8.9
Wade	1988	12	short	UBW	19
Van Sickels et al.	1988	51	short	Screws	1.3
Rubens et al.	1988	20	6m	monocortical plates	11
Kierl et al	1990	19	2y 9m	bicortical screws	10-63
Gassman et al	1990	50	intermediate	bicortical screws	0-25
McDonald	1990	22	6	monocortical plates	0 in 36/45
Lee & Piecuch	1992	15	6-24m	monocortical plates	1.5

***Method of fixation: UBW: Upper border wiring and intermaxillary fixation.**

mandibular or maxillary segmental osteotomies. All of the twenty cases were placed into IMF postoperatively, and the follow up period ranged from six to twenty one months.

Farrell and Kent assessed relapse cephalometrically, looking at anterior and posterior facial height and the SNA angle. The average relapse for anterior facial height in the inverted 'L' group was 31% of the correction, this relapse occurred within the five to seven month period. They found an average relapse of 5% in posterior facial height.

With the 'C' osteotomy group they found an average relapse of 23% of the original advancement in the horizontal plane, the maximum relapse was 50%. Most relapse occurred within the first four months postoperatively.

In an attempt to eliminate relapse, Reitzik (1980) developed a modified fixation technique for use with the inverted 'L' osteotomy. It consisted of fixing the proximal fragment to the distal fragment using vitallium mesh and screws. Cancellous bone from the iliac crest was then grafted to the osteotomy sites, and IMF was placed for a period from two to six weeks. The surgery was performed via an extraoral approach.

Serial cephalograms were then analysed using four linear measurements and two angles (SNB & the mandibular plane angle), to evaluate spatial changes in the proximal and distal fragments in both the anteroposterior and vertical planes. The series consisted of nine patients, the longest follow up period was twelve months and the shortest four months post release of fixation. Reitzik found no evidence of relapse in either the vertical or horizontal direction.

Reitzik et al. (1981) reports further on the stability of twelve of mandibular advancement using the inverted 'L' with rigid fixation cases that were evaluated 12 to 18 months postoperatively again no relapse was observed.

Barer et al. (1987) report a series of 43 cases of mandibular advancement using the inverted 'L' osteotomy with rigid internal fixation. The authors did not specify if the procedures were performed intra or extraorally. The age of the patients ranged from 13 to 56 years, all had the surgery performed by the same surgeon and IMF was only used on some patients and only for a maximum of four weeks. Cephalometric analysis was performed based on the method described by Lake et al. (1981). No mean postoperative relapse was demonstrated for the sample as a whole, although some individuals exhibited small amounts of relapse. No significant changes of the gonial angle, the proximal segment angle, nor the mandibular plane angle were observed over the long term.

Dattilio et al. (1985) report a series of 20 cases where the inverted 'L' osteotomy is used to close anterior openbites. Half of the cases were setbacks, the other half involved mandibular advancements, and all were performed via the extraoral route. No rigid fixation was used. Iliac crest bone grafts were placed in the osteotomy sites and all patients were placed into IMF for a period of eight weeks. Relapse was assessed cephalometrically by measuring the horizontal and vertical changes of B point relative to the SN line. They found a mean horizontal relapse of 11.4% (range 0 - 21%).

CHAPTER 5

FACTORS ASSOCIATED WITH POSTSURGICAL RELAPSE FOLLOWING MANDIBULAR ADVANCEMENT SURGERY

5.1 INTRODUCTION

The aetiology and mechanism of post surgical relapse following mandibular advancement is incompletely understood. Initially, attention was focused on which muscle forces are active on the mandible after operation and how they caused relapse. (Kohn, 1978; Ive et al., 1978; Poulton 7 Ware, 1973; Farrell & Kent, 1977; Gurnsey, 1974; Will & West, 1989; Epker et al., 1978; Epker et al.,1982) Reitzik (1980a) then focused attention to the rigidity between the proximal and distal fragments. Various factors reported to be associated with relapse following mandibular advancement include:

Orthodontics and occlusion
Magnitude of advancement
Condylar position
Proximal and distal segment positioning
Type of fixation.
Intermaxillary fixation
Maturity of bone union
Connective tissue forces
Vascular considerations of osseous segments
Growth
Other procedures

5.2 ORTHODONTICS AND OCCLUSION

In the preface to their book, Bell, Proffit and White (1980) noted that in the 1950's orthodontists had virtually no interest in surgery except for prognathism and surgeons had very little interest in orthodontics. By 1980 there were at least 100 different orthognathic surgical procedures, most of which were performed intraorally. They also noted that there was orthodontic involvement in almost all cases treated. Kierl et al. (1990) notes that presurgical orthodontics to remove dental compensations for skeletal malrelationships is preferred by most Oral Surgeons.

Various authors, including Poulton and Ware (1971), Egyedi (1980) and Kierl et al. (1990), believe that good interdigitation post operatively will help prevent relapse. This is in contrast to Tuinzing et al. (1989) who state that interdigitation appears not to be essential when the mandible is advanced in a clockwise direction. Egyedi (1980) states that in cases of severe disproportion he prefers no presurgical orthodontics, instead he favours orthodontics after bony consolidation. This seems a contradiction, however, he reports that he overcorrects surgically.

Epker et al. (1978) suggest that presurgical orthodontics cause inherent tooth mobility and thus a much higher frequency of skeletal relapse is to be expected. By this he means that during the period of IMF, if no rigid fixation is used, one could expect more relapse in cases which have had presurgical orthodontics. This is largely only of historical interest now, as rigid fixation is almost universally used for mandibular advancements

Epker et al. (1982) believes that dental compensations which are created by unstable orthodontic mechanisms (eg. extrusion of teeth or increases in transverse arch width) before surgery, may manifest as an anterior openbite following orthognathic surgery.

Reitzik (1980) noted a forward and upward movement of the mandible during the intermediate time period, following advancement of the mandible using the inverted 'L' osteotomy. He attributed this movement to be due to autorotation of the mandible in response to postoperative orthodontics.

5.3 MAGNITUDE OF MANDIBULAR ADVANCEMENT

Of all the variables studied this is the single most important factor linked to relapse. Multiple researchers including Lake et al. (1981), Van Sickels et al.(1986), Van Sickels et al. (1988), Will and West (1989), Gassman et al. (1990) and Kierl et al. (1990), found a highly significant relationship between the amount of relapse and the degree of advancement; ie, the greater the amount of advancement, the greater the amount of relapse. In fact Kierl et al. (1990) found that the amount of surgical relapse was the only variable that showed a significant relationship with post surgical relapse. Reubens et al. (1988) in their study of twenty patients who had mandibular advancement performed using bilateral sagittal split osteotomies found that advancements greater than 6 mm demonstrated the same magnitude of percentage relapse as those with lesser advancements.

While most researchers strive to find ways of reducing relapse, some accept it as inevitable. In an effort to create a Class I relationship some authors (Egyedi, 1980; Farrell & Kent, 1977; Poulton & Ware, 1973) advocate overcorrection, that is, putting the patient into a Class III incisal relationship and allowing relapse to occur. A hazard with this approach is that if the anticipated relapse does not occur the patient will have a resulting malocclusion.

5.4 CONDYLAR POSITION

The importance of correctly seating the condyles has already been discussed in Section 2.7.2

Schendel and Epker (1980) studied serial radiographs of 87 individuals who underwent surgical advancement of the mandible. They concluded that intraoperative distraction of the mandibular condyles from their functional position in the glenoid fossae results in dramatic skeletal relapse immediately upon release of IMF. This skeletal relapse occurs because a large discrepancy between centric occlusion and centric relation has been created. With the advent of rigid fixation one usually checks the mandibular advancement by releasing the IMF intraoperatively and letting the mandible rotate into the new centric relation. Any discrepancy from the preplanned position can usually be identified and corrected.

As previously discussed, in Section 2.7.2, the use of lag screws can theoretically torque the condyles into an unfavourable position. The alternative technique is to use non compression bicortical or positional screws, which should minimise torque on the condyles. (Jetter, 1984) McDonald et al. (1987) reported the use of non compression fixation across the osteotomy site with the proximal segment in a passive position. The authors believed this resulted in minimal torquing of the proximal segment. (Figure 2.13)

5.5 TYPE OF FIXATION

5.5.1 Rotational effects between fragments

McNeil et al. (1973), Bell et al. (1977), Ellis et al. (1983), Epker et al. (1978), and Gassman et al. (1990) all found that closing open bites (an anticlockwise rotation of the mandible) increased the rate of relapse. It is believed that the reason for this is that it increases the length of the pterygoid masseteric sling (see connective tissue forces: section 5.7). Will and West (1989) found no correlation between relapse and any of the cephalometric parameters; whereas Gassman et al. (1990) found that decreasing the mandibular plane increased the risk of relapse. Decreasing the mandibular plane angle is another way of expressing an anticlockwise rotation.

5..5.2 Rigid fixation between the proximal and distal segments

Prior to the advent of rigid fixation all patients undergoing mandibular advancement surgery were placed into IMF for variable periods of time. When rigid fixation between the proximal and distal segment was first introduced patients were generally still placed into IMF intraoperatively and for a variable period postoperatively. More recently techniques are described in which rigid fixation is used alone with only intraoperative use of IMF.

Spiessl (1974) was the first to use rigid fixation and his technique involved placing bicortical lag screws. His best results occurred with three screws per side. Many authors favour rigid internal fixation between the proximal and distal fragments. Many advantages are cited; first, there is an apparent increase in skeletal stability. (Spiessl, 1974; Reubens et al., 1988; Turvey & Hall, 1986; Kempf, 1987; Steinhauser, 1982; and Krekmanov & Lilja, 1986) Reitzik (1980) feels that the main cause of relapse is instability between the proximal and distal fragments under physiological forces for up to 25 weeks. Accordingly in an attempt to resist these forces he used a vitallium mesh plate and screws across the osteotomy site.

As already discussed, screw fixation can be accomplished with either the lag screw (compressive) technique as outlined by Spiessl (1974) and Kempf (1987) or it can be with the non compressive technique such as that used by Jeter et al. (1984). The screws can be placed via a trans buccal approach as advocated by Watze et al. (1990) or intraorally as described by Shepherd et al. (1991).

Turvey and Hall (1986) used 2 mm diameter screws for fixation, however Van Sickels and Flanary (1985) and Shepherd et al. (1991) advocate using larger diameter screws, for example 2.7 mm screws. They cite the advantage may be increased rigidity because more bone is engaged.

The tightness and immobility of a screw depends on its tract through compact cortical bone. Rigidity is only possible if the cortical bone is thick enough and if the compression between screw threads and bone is adequate. (Sevitt (1981) In an effort to increase the surface area of cortical bone exposed to the screw, Shepherd et al. (1991) angle the screws obliquely to the cortical bone.

Not all authors agree that screw fixation is more stable than wire fixation, Skoczylas et al. (1988) studied the short term stability of bimaxillary surgery consisting of Le Fort I impaction and bilateral sagittal split advancement. Fifteen patients had skeletal plus dental IMF and another group of fifteen patients had fixation of the mandibular advancements using bicortical screws. There was no statistical difference in post surgical stability between the two groups, in either the anterior-posterior plane, measured cephalometrically.

This was a well designed study but looks only at cases having bimaxillary surgery and the findings may not be applicable to mandibular surgery alone.

Hing (1989) investigated relapse following mandibular advancement using the bilateral sagittal split osteotomy in two groups. One group containing 22 subjects were fixated with wire fixation and the other group of 18 subjects had rigid fixation using bicortical screws. Both groups had comparable mean mandibular advancements. Relapse was assessed by comparing serial lateral head cephalometric radiographs. Hing found that the relapse tendency was higher in the screw fixation group, however this was not statistically significant. He found a mean percentage relapse of 32%. This was a well designed study which conflicts with other studies on the stability of screw fixation. Hing suggests a possible explanation for the apparent high rate of relapse may have been that screw fixation was a relatively new technique at the time of the study and may have involved a learning curve for the surgeons involved.

Rigid internal fixation initially involved the use of bicortical screws, however as the lingual plate of bone is thinner than the buccal plate, there may be an advantage in using monocortical plates and screws, engaging in the buccal cortex alone. This technique may also lessen the potential for nerve injury by avoiding compression of the proximal and distal fragments and by avoiding the need for the drill or screws passing near the nerve. Blomqvist and Isaksson (1994) compared the stability of bilateral sagittal split advancements using two types of fixation. One group consisted of 16 patients who had mandibular advancement and fixation with bicortical non-compressive screws inserted through a trans cutaneous approach. The other group of 22 patients had the bone segments fixed with unicortical miniplates on the lateral side of the mandible. Relapse was assessed by comparing serial lateral head cephalograms.

Statistical analysis showed no significant difference in postsurgical stability over the first six months post operatively.

Reubens et al. (1988) report on a series of 20 patients who had mandibular advancement performed using bilateral sagittal split osteotomies using osseous miniplates and monocortical screws. Skeletal relapse measured at B point was found to be 10.7% at a minimum of six months post operative (range -3 mm to + 2 mm).

Lee and Piecuch (1992) also used miniplates with monocortical screws for fixation following mandibular advancement using the bilateral sagittal split osteotomy. Their sample consisted of 15 patients, followed up for two years, they found an average relapse of 1.5% at B point (range -1 mm to +2 mm).

Hammer et al. (1995) used a three dimensional in vitro model to investigate the rigidity of fixation of the short sagittal split osteotomies using Association Osteosynthes (AO) plates with monocortical screws plus or minus bicortical screws. They found that greatest rigidity was obtained with the plate placed along the anterior border of the ascending ramus with the addition of interfragmentary screws. They note that with pure miniplate fixation the plate has to carry the whole functional load for which it was not designed.

The weight of evidence suggests that rigid fixation reduces relapse. This is well summed up by Kierl (1990) who states "rigid fixation does not provide consistently stable postsurgical results. However, when compared with previously reported relapse studies using nonrigid fixation techniques, rigid fixation yielded superior results."

5.5.3 Inter Maxillary Fixation

Prior to the advent of rigid fixation all patients undergoing orthognathic surgery were placed into IMF for variable periods of time ranging from two to ten weeks. (Reitzik, 1982) With the advent of rigid fixation the trend is generally to either not use any post operative IMF or to only use it for a short period of time. Some authors advocate the use of elastics to help reduce relapse following orthognathic surgery. (Hirose et al.,1976)

Will and West (1989) advocate that if advancements of greater than 9 mm are planned the more rigid fixation methods should be used and maxillo-mandibular fixation should be extended beyond the traditional six week period. They suggest that skeletal fixation may be the best option for these patients and even that may not completely prevent relapse.

Epker (1978) first advocated skeletal fixation and reported that it reduced relapse. As the name implies, wires are secured to the mandible and maxilla and then joined together usually with the placement of conventional interdental fixation. In the mandible the usual method of fixation is circumdental wires and in the maxilla, peralveolar, nasal aperture or circumzygomatic wires are used.

Ellis and Gallo (1986) in a study of twenty patients undergoing mandibular advancement with the bilateral sagittal split technique, used dental and skeletal fixation as outlined by Epker. They observed a statistically insignificant relapse of 8.9% in the short term (8 weeks), they concluded that their study indicated that the use of skeletal suspension wires is advantageous in the prevention of horizontal skeletal relapse.

Barker (1987) found that postoperative IMF inhibits auditory tube function mainly because yawning and gaping are prevented. These manoeuvres are thought to aid drainage of mucus produced in the middle ear and auditory tube, however the clinical significance of this is unclear.

5.6 MATURITY OF BONE UNION

There is much variation in the literature regarding the time taken for bone healing to occur across the osteotomy site. Boyne (1966) noted that various authors had advocated periods for immobilisation following the vertical subsigmoid osteotomy which varied from 12 days to ten weeks. Reitzik (1982) outlines the problems of investigating bone healing in humans as noninvasive monitoring is of limited use, he uses radiology as example, where radiological evidence of healing of a mandibular fracture may be delayed 18 months or more. Consequently several investigators have used animal models for investigation of bone union.

Boyne (1966) investigated bone healing following vertical subsigmoid osteotomies in Macaca resus monkeys. By administering tetracycline at various times post operatively and then sacrificing the animal and examining the mandible physically and under ultraviolet light, areas of bone deposition could be seen. He found that at 20 days post operative there was some mobility across the osteotomy site, but this was not discernible at 25 days. Tetracycline which had been administered at day 20 was observed to have been laid down as uniting callus between the proximal and distal fragments. From this Boyne concluded that immobilisation in man was required for four weeks as he believed the healing rates for man and the resus monkey to be equivalent.

Reitzik (1982) studied bone healing following mandibular osteotomy in the African Vervet monkey. A vertical osteotomy was performed in the posterior part of the ramus, rigid internal fixation was then applied and the animals were sacrificed at various post operative time intervals. The mandibles were removed, the fixation was removed and the mandibles then stress tested. His results indicated that full strength did not return to the mandible until 20 weeks post operatively, extrapolating this to humans he believed the equivalent time would be twenty five weeks. Reitzik thus believes that if no rigid fixation is used and only IMF placed for a six week period then spatial rearrangement between the proximal and distal fragment will occur. Interestingly Reitzik (1982) noted that many of the specimens sacrificed as early as ten weeks, showed bone formation covering the plates and screws.

Suuronen et al. (1992) undertook a series of experiments to investigate the effect of different fixation devices on mandibular body osteotomy healing in sheep. They compared the effect of fixation with either metallic plates (Group A) or absorbable poly-l-lactide plates (Group B). Eighteen adult Finnish sheep had vertical osteotomies performed under general anaesthesia on the left side of the body of their mandible. Internal fixation was then applied and the wound closed. Postoperative radiographs were first taken at 3 weeks, follow up times for radiology, microradiology and histology were 6, 12, and 24 weeks. The sheep were killed at either 6, 12 or 24 weeks.

The radiographs taken at three weeks showed that all but two of the sheep had good reduction of the osteotomy sites, two had what was considered satisfactory reductions. Slight callus was detected in four sheep and strong callus in two.

At six weeks visual inspection showed no obvious signs of infection or displacement in either group. In Group A prominent callus and bony union was seen in all specimens, microradiographic and histologic studies confirmed the degree of healing. In Group B radiographic analysis revealed heavy callus and consolidation in two cases, and no visible callus or sign of ossification in one case. In all three specimens one or more screws were loose.

At twelve weeks, five out of six osteotomies seemed well healed and showed no signs of infection. One case from Group B showed infection with pus formation, however good union was present. Radiographs showed that the osteotomy line was starting to disappears in all sheep. Two sheep from each group had what was classified as strong callus and one sheep from each group had what was considered weak callus. Histologic and microradiographic studies confirmed ossification.

At twenty four weeks all osteotomies in both groups were considered consolidated. Microradiographic and histologic studies confirmed these results.

Their results showed that both fixation systems are strong enough to secure fixation in sheep mandibles and also give an insight into bone healing in sheep.

Animal experiments can aid our understanding of bone healing in humans as in general the processes are similar to those occurring in humans. It is difficult to directly extrapolate these findings to humans as there are differences, notably in the rate of healing.

5.7 CONNECTIVE TISSUE FORCES.

In an effort to explain skeletal relapse various authors including; McNeil et al. (1973), Steinhauser (1973), Poulton & Ware (1973) and Epker et al. (1978), implicated the suprahyoid musculature. Poulton and Ware (1971) suggested the use of a neck brace to help overcome the forces associated with lengthening of the suprahyoid muscles. Bell et al. (1982) advocated the wearing of a cervical collar preoperatively in an effort to lengthen the suprahyoid muscles and thus reduce their effect on relapse. Others (Steinhauser, 1973; Epker et al., 1978; Epker et al., 1982) advocated suprahyoid myotomy to minimise relapse.

Reitzik (1980) states that these achieve only partial success because elimination of muscle activity is not only uncomfortable, but can only be limited in extent. Wessberg et al. (1981) believed that the suprahyoid muscles alone did not significantly influence relapse when they are stretched less than 30% of their resting length.

Solow and Kreiborg (1977) considered the suprahyoid musculature to be only one component of the paramandibular connective tissues which together with skin, interstitial connective tissue and periosteum all exert a posterior pull on the distal segment of the mandible following mandibular advancement.

Various authors, including Hovel (1964), believe that the powerful elevators of the mandible, in particular masseter and the medial pterygoid, will cause relapse if stretched beyond their normal resting length. He concluded that one method of avoiding this relapse would be to strip the mandible of the attachments of masseter and the medial pterygoid muscle. This practice however will compromise the blood supply of the mandible.

Yellich et al. (1981) investigated the effect of lengthening masseter muscle in rhesus monkeys and concluded that in surgical procedures where lengthening of the masticatory muscles is mandatory. It is beneficial to surgically detach muscles from their insertions. They believed this would place less stress on the newly placed surgically repositioned elements.

Kole et al. (1965) suggested that the inverted 'L' had less relapse than other procedures because the muscles of mastication were detached, thus minimising the effect of muscle forces on the associated bony segments.

Animal studies by Goldspink et al. (1976) implicated the mandibular periosteum as contributing a relapsing force on the distal segment. McNamara et al. (1978), cited in Epker et al. (1982), supported this concept and advocated incising periosteum at the osteotomy site in an effort to reduce tension.

Ellis and Sinn (1994) investigated the connective tissue forces generated during surgical lengthening of the mandible. The study involved 63 patients undergoing mandibular advancement, once the bony cuts had been made, a spring balance was applied to the distal segment and the amount of force measured that was required to bring the incisors into a Class I relationship. Aggressive stripping of the perimandibular periosteum was then performed and the force remeasured. For an average advancement of 6 mm they found the force required to advance the mandible was 1,498 g prior to muscle stripping and 778 g after muscle stripping. Clearly this is a significant force and is obviously only the passive force as, when the patient is awake, active forces will come into effect also.

5.8 VASCULAR CONSIDERATIONS OF OSSEOUS SEGMENTS

The maintenance of an adequate blood supply to the mandible following orthognathic surgery is of extreme importance if satisfactory healing is to be achieved. (Lownie et al., 1980) A common finding in the literature is the rounding of the gonial angle with time following mandibular advancement. Reitzik (1980) noted this occurrence following advancement of the mandible with the inverted 'L' osteotomy and attributed it to disappearance of the tip of the proximal fragment, possibly as the result of poor blood supply.

Bell et al. (1974), Investigated the blood supply to the mandible in rhesus monkeys using the oblique sliding osteotomy of the mandible. He determined that when the segments are pedicled, the intraosseous circulation was maintained. When the muscle and capsular ligaments were detached from the proximal segment a free osseous segment resulted and ischaemia, avascular necrosis and delayed healing, occurred.

Levine and Topazian (1976) noted that they have not encountered instances of necrosis of portions of the proximal fragment using the inverted 'L' osteotomy. They attribute this to the fact that the temporalis muscle and periosteal attachments to the superior border of the proximal fragment remain intact, providing a greater blood supply to the proximal fragment than is possible with the vertical sub sigmoid osteotomy.

This is in contrast to Lownie et al. (1980) who performed either 'L' or 'C' osteotomies on baboons, and found that the additional attachment of temporalis is of no advantage in enhancing the vascularity of that fragment. Ten baboons were included in the study. The method involved performing the osteotomy via an extraoral approach on one side of the mandible only, the other side had the same soft tissue surgery including muscle stripping but then had a silastic sheet placed over the bone prior to closure. At a postoperative period of 14 days the animals were killed, the mandible removed and examined microscopically. Histometric analysis showed avascular necrosis in some areas of the proximal fragments and to a lesser extent in the distal fragments, it was also seen on the control sides. The authors concluded that the periosteum and attached muscles of mastication play a small but significant role in the blood supply of the mandible, the remainder coming from the inferior alveolar arteries and the temporomandibular joint capsule. Although animal studies can aid our understanding of certain phenomena, there are limits to which we can extrapolate these results to humans. (Will & West, 1989)

If the blood supply to a segment has been compromised, this may first manifest as loss of the interdental papillae followed by loss of the supporting structures of the teeth. Omnell et al. (1994) describe a case where a 19 year old male who underwent a mandibular advancement osteotomy and genioplasty advancement presented one month postoperative with severe gingival recession, exposing labial root surfaces of the central incisors. It was, however, the author's opinion that the recession was probably the result of the genioplasty. There are few reports of mandibular gingival problems following orthognathic surgery, however there are several references to maxillary periodontal problems. (Yeo et al., 1989)

In assessing periodontal problems in orthognathic surgery patients one must remember that periodontal problems may have been caused by deep overbites or traumatic cross bites resulting in stripping of the affected gingiva prior to surgery. (Van de Perre et al.,1996).

5.9 GROWTH

When orthognathic surgery first became popular it was thought that surgical correction should be delayed until growth had ceased. The rationale for this thinking was based on two hypotheses: (1) favourable growth may occur and eliminate the deformity, and (2) surgery will interfere with subsequent growth and make the deformity worse.

Freihofer (1977) noted that there is no clinical or research evidence of undesirable growth following mandibular advancement surgery by conventional methods. Wolford et al. (1979) demonstrated convincingly that both of these hypotheses were not valid. They cite their own findings on growth data together with those of Bjork (1963) and Broadbent (1975) , which show that after five years of age the basic maxillo-mandibular relationship is established in more than 97% of individuals with mandibular deficiency. Further growth does not therefore alter the maxillo-mandibular relationship. To demonstrate that surgery did not interfere with subsequent mandibular growth, Wolford et al. published the results of a study in which 12 actively growing children, aged 8 - 16 years, had mandibular deficiency surgically corrected using bilateral sagittal split osteotomies. They showed, by using serial cephalograms, that following surgery they underwent normal growth with no ill effects, over a follow up period ranging from 2- 5 years.

Huang and Ross (1982) specifically examined the amount of advancement and its influence in mandibular relapse and stability in growing individuals. Their sample consisted of a total of 21 patients aged between 8.6 and 16.9 years, three had craniofacial anomalies and two had juvenile rheumatoid arthritis. They examined the stability of mandibular advancement in two groups; one with less than 10 mm of advancement, and one with advancements greater than 10 mm. In both groups there was cessation of growth for 1 year during which, presumably, neuromuscular adaptation occurred. Growth then resumed in more than half of the patients having less than 10 mm advancements. The group having advancements greater than 10 mm showed no resumption of growth, and in fact three of the ten patients, showed a continued decrease in mandibular length. The sample was followed for at least two years. They concluded that mandibular advancements loaded the articular cartilage, causing remodelling changes, and in the group with the larger advancements the loading was above the level which permitted mandibular growth.

Copray et al. (1984), cited in Will et al. (1989), also looked at the role of compressive forces on condylar cartilage using rat embryonic cartilage in culture. They found that in the cartilage was loaded with a force greater than 8 g it caused deformation and necrotic shrinkage of the condyles. Ellis and Sinn (1994) demonstrated forces greater than 700 g directed posteriorly when the mandible is advanced surgically. However one must remember that with function the force will be variable, and it may be that the mandibular cartilage responds very differently under normal function than cartilage in vitro.

Snow et al. (1991) looked at mandibular growth occurring post surgically in a group of 12 adolescents. Ten exhibited growth, as indicated by an increase in the distance from condylion to pogonion. In all cases the growth was expressed vertically relative to the cranial base, so that the chin did not come forward. They concluded that the results of mandibular advancement surgery can be acceptably stable after the adult growth spurt.

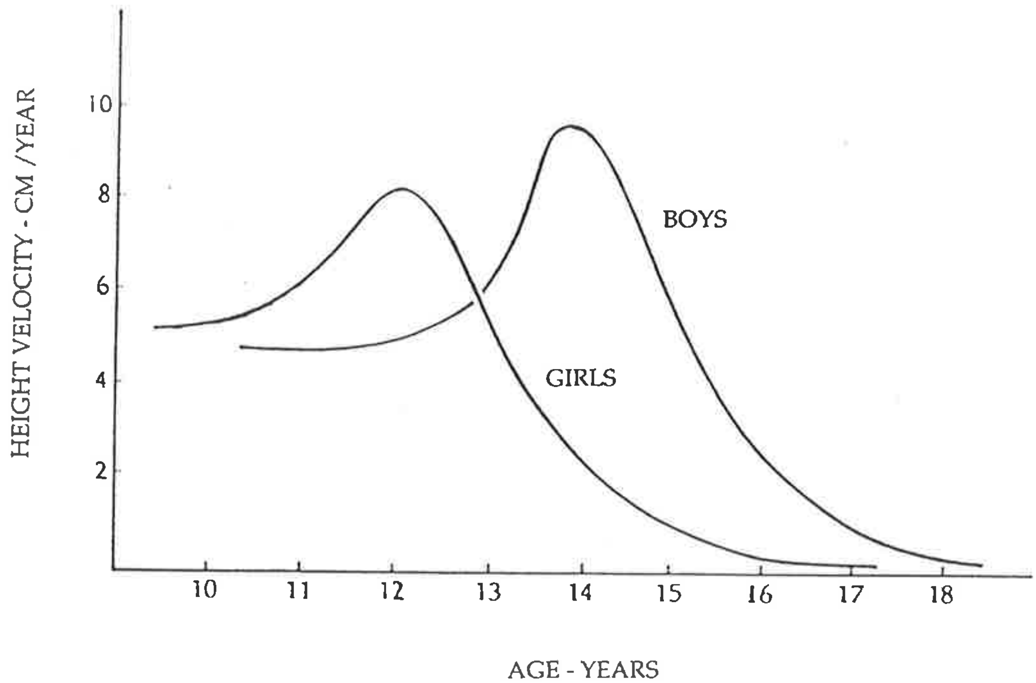
Post surgical growth can counteract the relapse tendency and this has been noted by Schendle et al. (1978), Wolford et al. (1978) and Freihofer (1982).

5.9.1 Normal growth

It has been known for many years that changes in the growth rate during the adolescent period can influence the course of orthodontic treatment. (Bjork, 1972; Grave, 1978 and Hagg, 1979) Growth can also affect orthognathic surgical planning as previously discussed, although it is generally accepted this is of greater significance in treatment of Class III malocclusions. (Proffit & White, 1970)

Males and females exhibit differences in growth, with females starting and finishing growth earlier than males. (Downs, 1956) Grave and Brown (1976) determined growth velocities for males and females. (Figure 5.1)

Figure 5.1 Average growth curves for males and females (From Grave and Brown, 1976)



5.10 OTHER PROCEDURES

Kahnberg and Ridell (1988) thought that amount of mandibular relapse was less when bimaxillary surgery was performed compared to single jaw surgery, they speculated that this was due to the shifts being proportioned between the two jaws.

Gassman et al. (1990) report that augmentation genioplasty and counter clockwise rotation of the chin are likely to increase relapse. However Kierl et al. (1990) investigating relapse in a group of patients who underwent mandibular advancement with the bilateral sagittal split osteotomy, found no statistically significant difference in relapse in patients having concurrent genioplasties.

McDonald et al (1987) reported on a series of 22 patients having mandibular advancement using bilateral sagittal split osteotomies, investigated the effect of four of these patients who also had vertical reduction genioplasties performed simultaneously. Two of the patients having the genioplasties also had anterior advancement genioplasties while the remaining two had posterior setback genioplasties. None of the patients who had genioplasties exhibited any relapse over the six month period of the study.

The removal of mandibular third molars preoperatively may make fixation easier after sagittal split osteotomy. The reason for this is twofold, first, the split is likely to be easier and, second, screw fixation is easier as there is likely to be more cortical bone present. For this reason Lindorf (1986) advocated removal of third molars some months prior to the osteotomy. This may obviously in some cases mean an extra general anaesthetic, increased morbidity and the thought of two procedures may deter some patients from having the osteotomy.

CHAPTER 6

INTERNAL FIXATION

6.1 INTRODUCTION

Internal fixation is applied to bone across a fracture or osteotomy site to resist the physiological forces which would otherwise move the fragments relative to one another. In discussing internal fixation of the mandible it is necessary to first consider the main forces acting on the intact mandible. Champy et al (1978) demonstrated that when the large elevator muscles of the mandible (temporalis, masseters and medial pterygoids) contract, they generate tensile stresses along the alveolar border and compressive forces along the lower border (Figure 6.1)

6.2 INTERNAL FIXATION FOR MANDIBULAR FRACTURES

The use of miniplates for osteosynthesis following mandibular osteotomies has already been discussed in Section 5.5. Most of these plating systems were originally designed for use in the treatment of facial fractures, included here is brief review of the literature regarding the use of internal fixation in treatment fractures of the mandible.

Archer (1961) describes the treatment of choice of mandibular fractures as being closed reduction using arch bars and intermaxillary elastics whenever possible, however he describes numerous other methods. These include extraoral skeletal pin fixation, internal wire fixation and internal fixation using 'Sherman' bone plates. Interestingly, Archer notes that since the introduction of external skeletal fixation he has found it less frequently necessary to use plates.

Open reduction and internal fixation of mandibular fractures did not gain wide acceptance until Champy et al. (1978) described the use of monocortical miniplates. These plates were used without compression and without IMF, and could be placed via the intraoral route. They emphasise the use of a low speed drill with irrigation, and state that it is important to contour the plates so that they are passive. In all they treated 183 mandibular fractures with up to five years follow up, there was no failure of fixation. The patients could eat soft food on the first postoperative day and could eat normal food by day ten. Infection was found in 3.8%, malunion in 0.5% and delayed union in 0.5%. The occlusion needed adjustment in 4.8% of patients.

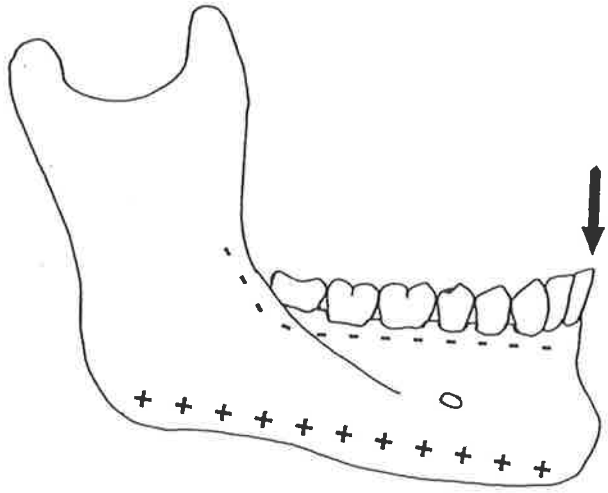
The philosophy of Champy et al. is based on the assumption that the mandible functions as a beam, such that during mastication the upper border of the body of the mandible is subject to tensile forces while the lower border is under compression. (Figure 6.1) This was based on clinical and laboratory studies, resulting in the authors describe the ideal line of ostoesynthesis . Only one plate is needed for mandibular fractures, with the exception of the anterior region where they found two were needed due to the presence of torsional forces. They state that the use of too rigid a plate is inadvisable because it will result in stress shielding. Champy advocates treating mandibular fractures as early as possible, this reduces the incidence of complications.

In contrast to Champy et al. other authors are of the opinion that rigid osteosynthesis is not obtainable without bicortical engagement of the screws. (Becker, 1974; Schilli, 1977; Souyris, 1980 and Luhr, 1982) Several authors believe compression of the fragments is essential for primary bone healing.

Figure 6.1 Mandibular strains (Modified from Champy 1978)

Tensile stresses along the alveolar border: (-)

Compressive stresses along the lower border: (+)



(Becker ,1974; Schilli, 1977; and Luhr, 1982) Theriot et al. (1987) conclude that the question as to whether rigid maxi-systems are necessary or if mini-systems will suffice has never been definitively answered.

Compression plates are designed with at least one eccentric hole and an inclined plane, such that as the screw is tightened the bone fragments are placed under compression. An adaptive plate has circular holes and if it has been correctly adapted to the bone surface, should not produce any movement of the fragments relative to one another as the screws are tightened.

Shetty et al. (1995) investigated fracture line stability as a function of the internal fixation system using an in vitro mandibular angle fracture model. Six different methods of fixation were compared with respect to their ability to restrain relative motion at the fracture site under simulated occlusal loads. The compressive system included: (1) eccentric dynamic compression plate, (2) Wurzburg compression plate, (3) Luhr plate, (4) solitary lag screw technique. The adaptive plates used were the Champy miniplate and the Mennen plate. Their results indicated that there was little difference in the stability of the various compressive systems, however the stability provided by the adaptive and compressive systems differed significantly. Even at low masticatory loads the adaptive system had an instability that was two to three times as much as the compressive systems. It is important to point out that the plates were placed according to the manufacturers instructions, the Champy plate being placed on the upper border and the Wurzburg plate being placed on the lower border. Thus the differences in stability reported may be a function of the plates position in the testing apparatus rather than any intrinsic superiority of the Wurzburg plate. The authors noted that contrary to the cantilever beam model, the angle is subject to other forces such as torsional forces when a load is applied to the contralateral side. Champy and Kahn (1995) were quick to defend the Champy plate, pointing out that while forces other than tension are present at the upper border, in a fracture situation, the neutralization of the forces of traction is enough to suppress the adverse effects of the other forces. They also point out that their research work has shown that the maximum bite force in a patient with a fractured mandible is much less due to pain, than in a healthy patient. The authors state that clinical experience has shown that the Champy system works well.

Choi et al. (1995) also investigated miniplate fixation of angle fractures in an in vitro model and concluded that to achieve early mobility with assured stability in the case of mandibular angle fractures their findings support the use of two miniplates.

6.3 INTERNAL FIXATION FOR OSTEOTOMIES

Rahn (1989) and Kroon (1991) note that non comminuted mandibular fractures provide buttressing bone which helps provide stability if a plate is used for fixation. The situation is very different for an osteotomy site, because the plate has to carry the entire functional load. As already discussed, the research by Hammer et al. (1995) suggested that a single miniplate with monocortical screws is probably inadequate for fixation of an osteotomy site if no IMF is used. In their model they found that for the short sagittal split stability of fixation could be enhanced by placing the plate in an anterior position on the ramus.

Another fundamental difference between mandibular fractures and osteotomies is pointed out by Reitzik (1982), he believes that the reason why mandibular fractures that have been immobilised for six weeks seldom show evidence of plastic deformation is that almost all fractures (apart from the subcondylar variety) lie anterior to the leading edge of the pterygomasseteric sling and are thus not affected by the forces of the three major jaw elevators. Only the suprahyoids remain to displace the fracture and these are too weak to cause any rotatory displacement of the distal fragment.

Osteotomies of the mandible, however, are almost all in the ascending ramus within the influence of the pterygomasseteric sling. Reitzik believes that if rigid fixation is not used when IMF is released at six weeks, then the jaw elevators can cause considerable rearrangement of the proximal and distal fragments.

Reitzik and Schoorl (1983) report that rigid screw fixation promotes rapid healing, while Krekmanov and Lilja (1986) cite earlier return to function and greater patient comfort as advantages of rigid fixation.

Since the advent of rigid fixation it was generally accepted, since the screws were made of biocompatible metals, that they needed no removal operation. (Ikemura et al., 1988) However Moberg et al. (1988) demonstrated that titanium alloy implants released large amounts of aluminium, accordingly many centres now advocate removal of screws once the osteotomy sites have healed. Reubens (1988) and McDonald et al. (1987) advocates removal of miniplates and screws used for fixation of osteotomy sites and he reports that in some cases the plates cause irritation of the overlying mucosa.

Several authors have subsequently experimented with resorbable screws. Obwegeser (1994) published a series of 12 patients who had bilateral sagittal split osteotomies performed using screws made from allogenic cortical bone. The screws were heat sterilised to eliminate the possibility of cross infection. Initial results are encouraging with no postoperative problems and stability seems comparable to conventional metallic screws. Suuronen et al. (1994) experienced similar results in a series of nine patients also undergoing bilateral split osteotomies using screws made from self reinforced poly-L-lactide. Resorbable screws have the obvious advantage that they are bioconvertible and therefore no removal operation is needed.

CHAPTER 7

NEUROSENSORY FUNCTION

7.1 INTRODUCTION

The reported incidence of injury to the inferior alveolar nerve following ramus osteotomies is highly variable and ranges from 0.025% to 84.6% according to LaBanc and Gregg (1992). They believe that the wide range is largely due to the sensory testing methods used rather than actual degree of injury. Studies with the lowest incidence of sensory disturbance use crude methods of sensory testing and tend to be retrospective. Studies that report higher incidences of sensory disturbance tend to use very sensitive testing methods and are prospective. Inferior alveolar nerve injuries can cause sensory disabilities for the patient and expose the surgeon to liability claims. (Jones, 1992)

7.2 BASIC CONCEPTS OF NERVE INJURY

Peripheral nerves in mammals are made up of many axons bound together in a fibrous envelope called the epineurium. (Ganong, 1991) The axons or fibres can be divided into A, B, and C groups, the A group is further divided into a, b, g, a and d fibres. Each family of fibres has various speeds of conduction, different diameters, different electrical characteristics and different functions. Within a sensory nerve the larger axons are concerned primarily with proprioceptive sensation, while the smaller ones subserve pain and temperature. Ganong (1991) notes that the different fibres respond differently to injury, for example, pressure to a nerve may cause loss of conduction in touch and pressure fibres, while pain sensation remains relatively intact. Thus in considering sensory nerve function in the clinical context, it is important to understand the underlying basic physiology.

Ghali and Epker (1989) have divided neurosensory testing into two basic categories, mechanoceptive and nociceptive. Mechanoceptive testing is further divided into two-point discrimination, static light touch and brush directional stroke. Nociceptive testing is subdivided into pinprick and thermal discrimination. They report that two-point discrimination is designed to test slowly adapting A alpha sensory nerve fibres. The sensation of static light touch and brush directional stroke are designed to test quickly adapting A alpha sensory nerve fibres. Pin prick tests are for myelinated A delta nerve fibres; whereas temperature discrimination selects myelinated and unmyelinated A delta and C sensory nerve fibres.

LaBanc and Gregg (1992) state that the management of a nerve injury depends upon the classification of the nerve injury and the nature of the injury. Several classification schemes of nerve injuries have been proposed and it is beyond the scope of this work to review these, other than perhaps to briefly mention the most widely used classification system, proposed by Seddon (1943), in which he divides nerve injury into neurapraxia, axontmesis and neurotmesis.

Neurapraxia is a conduction block as a result of a mild injury, usually causing a low level of sensory disturbance. Recovery is complete and usually takes from hours to days. There is no axonal degeneration.

Axontmesis is a nerve injury where there is degeneration of the distal portion of the axon but, because the endoneurial tube is preserved, there is regeneration. Clinically the injury usually manifests as a severe paraesthesia from which recovery takes several months and is usually incomplete.

Neurotmesis is where the nerve trunk is severed. Clinically there is either anaesthesia or dysaesthesia. The chances of significant improvement are small without surgical intervention.

7.3 METHODS OF NEUROSENSORY TESTING

Campbell et al. (1987) emphasise that to evaluate nerve dysfunction it is important to perform objective testing and not to rely solely on the patients subjective opinion. Similarly, LaBanc and Gregg (1992) note that when the patient suspected of having a nerve injury is examined, as well as interviewing the subject, it is important to quantify stimulus detection, localisation and perception disturbances.

Robinson et al. (1992) stress the importance of carrying out neurosensory testing in a quiet room with both the patient and examiner relaxed. They recommend that the patient should have their eyes closed and should indicate the detection of a stimulus by raising a finger. Various techniques have been reported for neurosensory testing, some require only simple equipment, whereas others require complex apparatus.

Leonard in 1973 and Robinson in 1983 found evidence to suggest that following injury to a sensory nerve trunk, there is collateral reinnervation. However the extent to which this occurs with the inferior alveolar nerve is not known. Mapping the area of sensory disturbance is thus helpful.

Two Point Discrimination

Campbell et al. (1987) reported that normal range two point discrimination in the trigeminal distribution is 7-14 mm. From 15 - 20 mm it is considered diminished and above 20 mm is absent.

Robinson (1988) tested two point discrimination by using ten pairs of blunt probes with varying separations. Kawamura and Wessburg (1985) used an E.C.G. calliper to test two point discrimination. The points of the calliper were set at 10 mm and closed as accurate responses were obtained.

Ghali and Epker (1989) used a device which is commercially available in the U.S.A. known as the Two Point Pressure Anesthesiometer, this is a device with two filaments which are applied to the skin until they bend. Robinson et al. (1992) describe how to make a simple device for two point discrimination, it is a ten sided acrylic disc with wires placed on the outer edges of the disc. The wires are blunt and have separations of 2 - 20 mm at 2 mm intervals. The wires are drawn across the skin surface, maintaining as constant a pressure as possible and the patient is asked to say whether they feel one or two stimuli. The authors report that in normal patients the two point discrimination varies widely in different regions: thresholds are 2 - 4 mm on the lip and 8 - 10 mm on the skin on the lower border of the mandible.

Static Light Touch

This test has traditionally been performed using a wisp of cotton wool, however in an effort to increase consistency, Robinson (1988) used a Von Frey hair (bending force 1 - 8g) to map out any areas of anaesthesia. The area was then outlined with a pen and a photograph taken of the patient whilst their head was held in a cephalostat. This allowed longitudinal comparison to assess any change. Zuniga and Essick (1992) and Murray et al. (1994) advise that static light touch should be assessed using a commercially available devices known as Semmes - Weinstein pressure aesthesiometers. These are essentially mono-filament fibres of different stiffness. These filaments are standardised Von Frey hairs. Blackburn (1990) and Robinson et al. (1992) describe how a simpler and cheaper version of this device can be constructed by gluing a 2 cm length of 3/0 prolene onto a perspex rod. The force required to bend this is approximately 2 g.

Direction Discrimination

Gkali and Epker (1989) suggest using the baseline Von Frey hair for this test and advocate random movements of the hair in 1 cm strokes, either from right to left or from left to right, and the patient reports which direction the hair is moving. Zuniga and Essick (1992) describe a similar method but use a soft brush such as a number 2 camel hair. Murray et al. (1994) investigated the effect of stimulus force on perioral direction discrimination and concluded that a hair which supplies a force ten times greater than the subjects 'threshold hair' should be used for tests on direction discrimination. Robinson et al. (1992) did not feel that direction discrimination tests were a necessary part of simple sensory testing.

Thermal Discrimination

Various pieces of equipment have been used for this test, Ghali and Epker (1989) used a cotton tipped applicator saturated with ethyl chloride and then applied lightly to the skin. As a control he used a plain cotton tipped applicator, the subject had to determine whether or not they felt cold. Robinson (1988) and Naples et al. (1994) describe a method of testing thermal sensitivity using a probe with a tip diameter of 1 mm and having a temperature of either 0°C or 45°C. The patient was asked whether they felt hot, cold or just pressure. Zuniga and Essick (1992) published values for pain detection and pain tolerance threshold for various sites on the face, for the lower lip they found these values to be 47° and 50°C respectively. Again Robinson et al. (1992) did not consider thermal testing a routine part of simple neurosensory testing.

Pinprick (Pain) Sensation

Ghali and Epker (1989) advocate using a 22 or 23 gauge needle for this test, it is applied to the skin with enough force to draw blood. Robinson et al. (1992) and Robinson (1988) feel that there is no need to cause bleeding and suggest that a more controlled method is to make a device as described by Sunderland in 1978, which consists of a needle or pin attached to a coil spring which can deliver a force of up to 15 g. The authors note that if there is no area of anaesthesia to light touch then there will be no area of anaesthesia to pinprick, however if a nerve injury is present then the force with which a pin needs to be applied to evoke a sensation of pricking can be determined.

Robinson (1988) also advocated pulp testing the involved teeth and used an electric pulp tester for this purpose.

Somatosensory evoked potentials were first described by Dawson (1947). They are E.E.G. changes which occur in response to peripheral sensory nerve stimulation. Pogrel (1992) reports that reproducible recordings can be produced from the sensory cortex upon stimulation of the lower lip. The authors report that this method of testing sensory nerve function appears to represent an objective method of monitoring trigeminal nerve activity, however they caution that until further work is carried out in this area somatosensory evoked potentials will remain a research tool only.

7.4 INTERPRETATION OF NEUROSENSORY TESTING

Robinson (1988) performed several types of neurosensory tests on several groups of patients with known nerve injuries and made several conclusions. He found that the method used was not always capable of demonstrating an abnormality that was reported by the patient. He found that the tests most likely to detect an abnormality were localisation, thresholds to pinprick and two point discrimination. No areas of complete anaesthesia to light touch remained four months after nerve compression and eight months after nerve section. There was little improvement in sensation after nine months post compression and twelve months post-section injury. Robinson also concluded that return to normal two point discrimination and localisation indicated that the sensory loss arose from nerve compression and not nerve section.

Van Sickels et al. (1989) compared the normal sensibility of the infraorbital nerve to the ipsilateral inferior alveolar nerve by using a battery of neurosensory tests. There were thirty subjects with a mean age of 26 years. They concluded that the infraorbital nerve is an acceptable control for retrospective studies of the inferior alveolar nerve.

Pogrel (1992) observes that currently used methods of clinically testing the trigeminal sensory nerve function rely almost entirely on subjective testing. He questions the importance of each of the senses tested and points out that they cannot be used in animal studies.

7.5 NEUROSENSORY DEFICITS ASSOCIATED WITH BILATERAL SAGITTAL SPLIT OSTEOTOMY

Various authors have looked at the incidence of neurosensory changes following bilateral sagittal split osteotomies, however because there is no standard method of sensory testing it is difficult to directly compare the results among investigators. (Table 7.1)

With the sagittal split osteotomy fixation using the non compression technique is reported to exert less compression on the inferior alveolar nerve McDonald et al (1987) Although a study by Nishioka (1987) found no evidence of increased labial paraesthesia using the compression technique.

7.6 NEUROSENSORY DEFICITS ASSOCIATED WITH THE INVERTED "L' OSTEOTOMY

It has been shown that with mandibular setbacks there is less risk to the inferior alveolar nerve with vertical subsigmoid osteotomies than with bilateral sagittal split osteotomies according to Naples et al. (1994). However they point out that with the intraoral inverted 'L' osteotomy the soft tissues on both the medial and lateral side of the mandible are raised and hence one cannot assume that the same low incidence of nerve injury will exist for this osteotomy. To investigate this further they compared two groups of patients who had mandibular setback surgery performed by the same surgeons. Ten patients underwent bilateral sagittal split osteotomies and nine patients underwent inverted 'L' procedures, the average age of the patients was 28 years. Neurosensory testing was carried out at an average postoperative time of thirteen months, and involved answering a questionnaire and undergoing three tests of neurosensory function.

Table 7.1 Review of the literature on sensory changes in the lower lip after sagittal split osteotomies of the mandible.
(after McDonald et al., 1987)

Author	Number of Patients	No Sensory Change*	Parasthesia*	Anaesthesia
Alfaro et al (1969)		87.5% (2yr)	12.5%	-
Freihofer & Petresevic (1975)	38	51% (PO) 78% (2yr)	41% (PO) 20% (2yr)	8% (PO) 2% (2yr)
Souyris (1978)	25	84% (6yr)	12% (6yr)	4% (6yr)
Pepersack & Chausse (1978)	67	-	60% (5yr)	-
Schendel & Epker (1980)	87	-	24% (11mo)	-
Brusati et al (1981)	20	52.5% (PO) 97.5% (2mo)	45% (PO) 2.5% (1yr.)	-
Macintosh (1981)	236	-	85% (PO) 9% (1yr.)	-
Simpson (1981)	100+	87.5 (2yr.	12.5 (2yr.)	-
Paulus & Steinhauser (1982)	221	-	87% (PO;BCS) 90%(PO;wire) 57% (1yr;BCS) 50% (1yr;wire)	-
Martis (1984)	258	-	86.8% (PO) 2.3% (2yr)	-
Turvey (1985)	128	-	3.5% (2-5yr)	3.5% (PO)

**Postoperative time interval is given in parenthesis. (PO) immediate postoperative;* (BCS) *bicortical screw fixation of segment.*

These consisted of brushstroke detection, light touch threshold and thermal sensitivity. They found no significant differences between the surgical groups on analysis of the neurosensory tests, however analysis of the data from the questionaire indicated that the bilateral sagittal split group were significantly more likely to report hypoaesthesia of the lower lip.

III

MATERIALS AND METHODS

CHAPTER 8

STUDY POPULATION

8.1 STUDY DESIGN

The study was both retrospective and prospective, the retrospective arm consisted of retrieving the names of all patients who had undergone mandibular advancement for the correction of mandibular deficiency from the records of the South Australian Oral and Maxillofacial Surgery Unit and from the private practice of one surgeon (R. H. B. J.).

The prospective arm consisted of those patients having mandibular advancements performed by one surgeon (R. H. B. J.) in the Royal Adelaide Hospital after 1st October 1993. In October 1993 it was decided that all patients admitted via the South Australian Oral and Maxillofacial Surgery Unit to the Royal Adelaide Hospital under one surgeon (R. H. B. J.) for correction of isolated mandibular deficiency would have mandibular advancement performed using the intraoral inverted 'L' osteotomy. Those patients requiring bimaxillary surgery where large mandibular advancements were required were treated using extraoral inverted 'L' osteotomies in conjunction with maxillary surgery.

Patient details were recorded and cephalometric radiographs were collected from the patients files.

The records were accepted for study if the following criteria were met:

(i) Surgery was limited to mandibular advancement alone or combined with a maxillary osteotomy.

(ii) The patient was operated on by one surgeon (R. H. B. J.).

(iii) A minimum of three lateral ceph radiographs were present:

T1: preoperative

T2: immediate postoperative (within 7 days)

TL: the latest postoperative.

For the prospective subjects it was planned to take preoperative (T1), immediately postoperative (T2) followed by:

T3: 3-11 weeks postoperatively

T4: 12-26 weeks postoperatively

T5: 27-52 weeks postoperatively

T6: 53-104 weeks postoperatively

T7: >105 weeks postoperatively

Of the 17 prospective patients who had intraoral inverted 'L' osteotomies performed, a total of 14 patients were included into the study. The remaining three were excluded due to incomplete radioghraphs.

Of the 16 prospective patients who had bilateral sagittal split osteotomies performed, 11 were included into the study

Of the 6 prospective patients who had extraoral inverted 'L' osteotomies combined with maxillary surgery, 3 were included into the study.

Of the 20 retrospective patients, only 5 were included in the study, of these 4 had bilateral sagittal split osteotomies and one had an extraoral inverted 'L' osteotomy combined with maxillary surgery.

The patients who were excluded were because of incomplete radiographic records.

The patients who had isolated mandibular surgery had no known syndromes or physical disabilities. Three of the patients who had bimaxillary surgery had a history of juvenile rheumatoid arthritis which was not active at the time of surgery.

The total number of lateral cephalograms included for analysis was 124.

All patients received presurgical and postsurgical orthodontic treatment.

8.2 SURGICAL TECHNIQUE

8.2.1 Intraoral inverted 'L' technique.

Patients had an endotracheal general anaesthetic with hypotension to 90mm Hg. (systolic). The medial and lateral aspects of the mandible were infiltrated with 2% lignocaine with 1:80000 adrenaline. An intra oral incision was made similar to that for a B.S.S.O. extending from the lateral aspect of the mandibular body up the external oblique ridge. Subperiosteal dissection was carried out on the medial side of the ramus to expose the lingula and the sigmoid notch; on the lateral side a similar dissection was performed including stripping the masseter muscle to expose the angle of the mandible. The horizontal cut was then performed above and behind the lingula with the inferior dental nerve under direct vision. This was carried out on both sides of the mandible using a recriprocating saw. The teeth were then placed into centric relation and held there by an interdental wafer (C.R.) and intermaxillary fixation. An eight hole Wurzberg plate was placed from above the horizontal cut on the mandible to the zygomatic buttress of the maxilla. (Figure 8.1) This plate was used to control the proximal fragment and to ensure the condyle was seated. With the I.M.F. still in position the vertical cut was carried out using the sagittal saw with the 100° angled blade, from the most distal aspect of the horizontal cut to the angle of the mandible, thus avoiding the inferior dental nerve.

The I.M.F. was released and the dentate segment of the mandible advanced into the new position. I.M.F. was placed with the final wafer in position. Two "L" plates are placed via the trans buccal approach, one plate was placed at the anterior border, the other at the angle. (Figure 8.2)

The defect was grafted with bone taken from the lateral aspect of the mandible usually unilaterally, except for large advancements in which case bone was harvested from the lateral aspect of the mandible bilaterally. The incision was sutured, the I.M.F. was released and the wafer removed. Intra operatively the patients were given I.V. dexamethasone (8mg. 12 hourly and I.V. cephalothin. 1 g. 6 hourly) The patient was extubated in theatre and returned to the ward with jaws free. Dexamethasone and cephalothin were continued for 48 hours post operatively and a non chew diet implemented. Most patients were discharged on the third day post operatively and reviewed closely during the recovery period. Initially the wafer was wired to the maxillary dentition for several weeks postoperatively to act as a guiding splint but this practice was discontinued after January 1995.

Figure 8.1 Condylar positioning plate used for intraoral inverted 'L' osteotomy

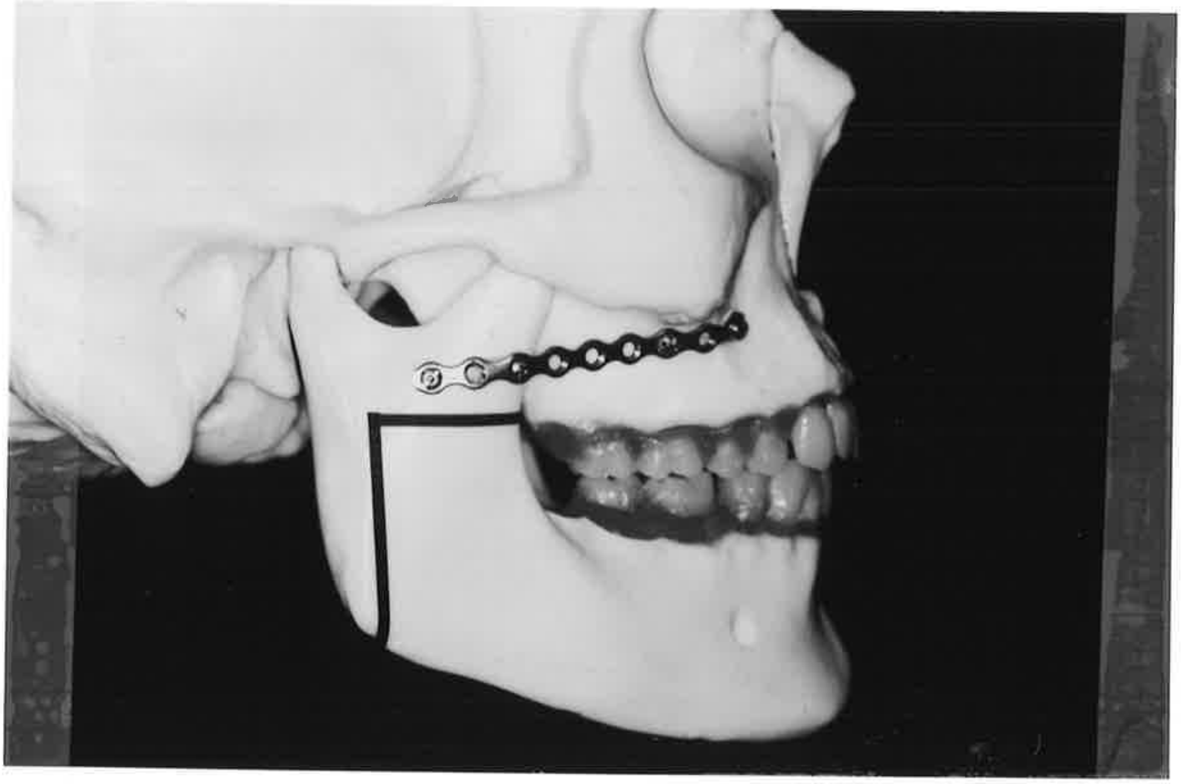
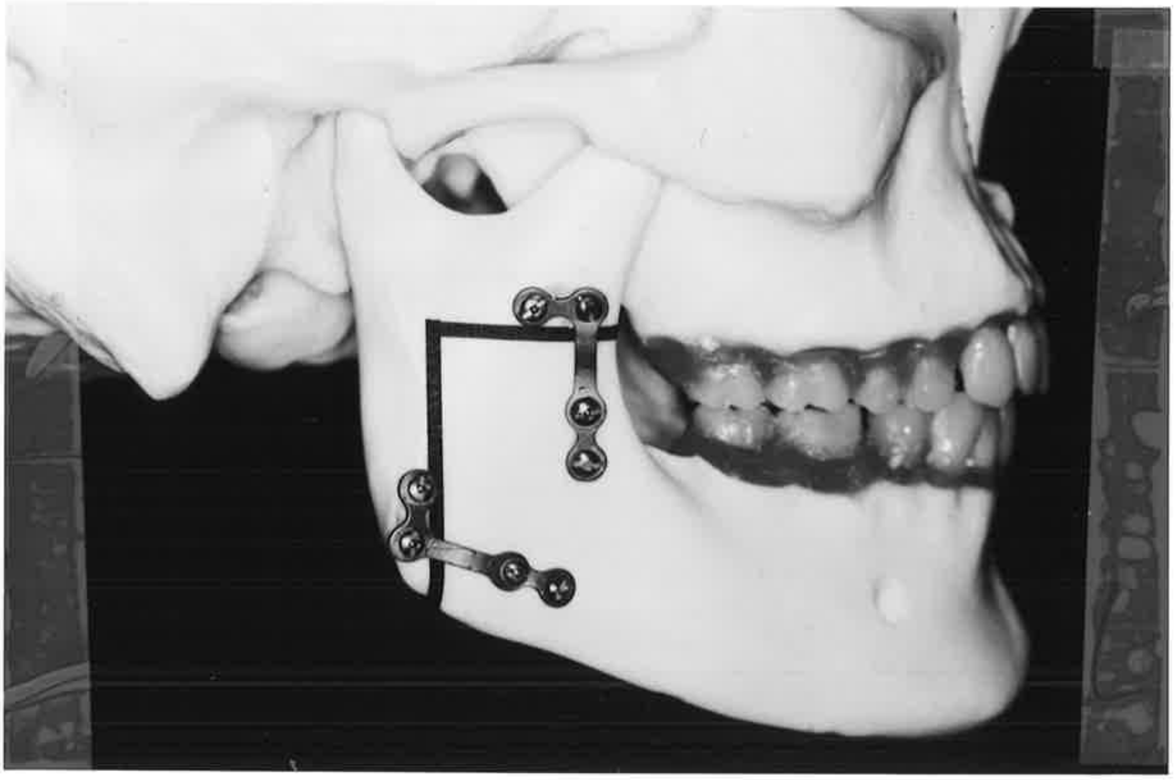


Figure 8.2 Fixation plates plate used for intraoral inverted 'L' osteotomy



8.2.2 Bilateral sagittal split technique

The technique used was based on the method described by Trauner and Obwegeser (1957) and modified by Dal Pont (1961) and Hunsuck (1968). The same perioperative pharmacological regime as for the intraoral inverted 'L' osteotomy was employed, and the same hypotensive anaesthesia was administered. The osteotomy cuts were performed using a recriprocating saw for the horizontal and vertical ramal cuts and a sagittal saw for the sagittal cut. The splits were initiated by driving a fine osteotome from the sagittal cut inferiorly just medially to the buccal plate down to the lower border and then through the lower border. Once the distal segment was mobilized it was advanced into a wafer and held there with wire intermaxillary fixation while rigid fixation in the form of three bicortical positional screws per side were inserted via a trans buccal approach. The intermaxillary fixation was then removed, the occlusion checked and if satisfactory the incisions were closed.. As with the intraoral inverted 'L' osteotomy the wafer was initially wired to the maxillary dentition for several weeks postoperatively early in the series but this was discontinued after January 1995.

8.2.3 Technique for extra oral inverted 'L' and Le Fort I osteotomy.

The same perioperative pharmacological regime as for the intraoral inverted 'L' osteotomy was employed, and the same hypotensive anaesthesia was administered as for the intraoral inverted 'L' and bilateral sagittal split osteotomies. The Le Fort I osteotomy was carried out in a manner similar to the method described by Bell (1975). Fixation was obtained by the application of two four hole L shaped Wurzburg mini plates per side. The surgeons then regloved and performed the extra oral osteotomy via an incision placed two centimeters below the lower border of the mandible as described by Datillio et al (1985). The osteotomy was then carried out using a bur, placement of the cuts was in the position described by Reitzik (1976) with the intersection of the horizontal and vertical cuts being approximately 8 mm above and 11 mm behind the midpoint of the waist of the ascending ramus. This resulted in an osteotomy in roughly the same position as that of the intraoral inverted 'L' osteotomy but avoided the need to expose the medial side of the ramus. On completion of the cuts the distal segment was then mobilized and advanced into the wafer, intermaxillary fixation was applied and fixation applied as for the intraoral inverted 'L' osteotomy except that the plates were applied directly. The intermaxillary fixation was removed the occlusion checked and if satisfactory the wounds were closed, taking care to close the extraoral incision in layers.

8.3 RADIOGRAPHIC TECHNIQUE

Radiographs were taken at either the Radiology department at the Dental hospital or in the private rooms of R.H.B.J., depending on whether the patient was a private or public patient.

The Dental Hospital Radiology department used:
TMAT6, Ortho M or Cronex Lodose or Fuji double emulsion film. The film type was chosen at the discretion of the radiographer and inserted into a *Kodak Lanex* regular cassette with *Kodak Lanex* regular screens. The cassettes were placed into a *Kodak Lanex* film holder. A standard film to mid sagittal plane distance of 16 centimetres was used.

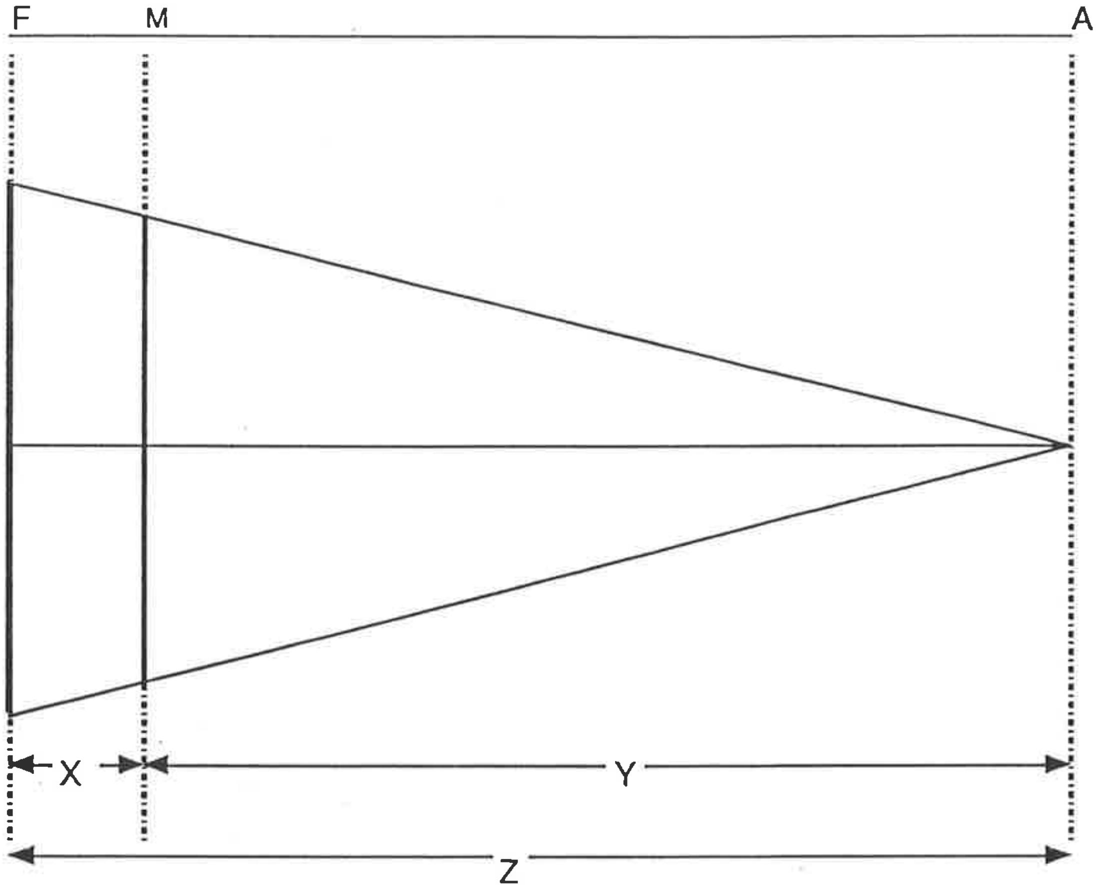
The X- ray source was a *Philips super 50 CP/80* unit (machine A). A *Kodak RP X-Omat* film processor and later a *Fuji FPM 2100* x-ray processor was used to process the films. The enlargement factor (Figure 8.1) was calculated by Farrer (1984) using the same facilities.

R.H.B.J. used:

Konica double emulsion film, inserted into a *Rego* regular cassette with *Kodak Lanex* regular screens. The X- ray source was a *Plan Mecca 2002cc* (machine B). A standard film to mid sagittal plane distance of 13.5 centimetres was used. Radiographs were developed in a *Velopex extra 'X'* processor. The enlargement factor was calculated using the method shown in Figure 8.3, and the results shown in Table 8.1.

A standardised technique for lateral head cephalograms was followed as outlined by Farrer (1984). The patient was positioned in a *Lumex* cephalostat whilst standing upright with the Frankfort horizontal plane parallel to the true horizontal. Patients were asked to bite gently with their back teeth together and to relax their lips.

Figure 8.3 Calculation of the enlargement factor for points lying on the mid-sagittal plane (Hing 1989).



F = Film plane

M = Mid-sagittal plane

A = Focus

X = Object to film distance

Y = Object to focus distance

Z= Focus to film distance

E = Enlargement Factor

$$E = 100 \times \left[\frac{Z}{Y} - 1\right]$$

Table 8.1 Enlargement factors of the X ray Machines

MACHINE A	MACHINE B
X= 160 mm	X= 135 mm
Y= 1818 mm	Y= 1500 mm
Z= 1978 mm	Z= 1635 mm
E= 8.8%	E= 9.1 %

8.4 TRACING AND DIGITISING PROCEDURE

Each of the 124 radiographs was placed over a lighted viewing box in a darkened room. A sheet of acetate tracing paper was secured to the radiograph with adhesive tape at the superior and inferior margins. The hard tissue details were identified and traced onto the acetate with a sharp Hb pencil. The hard tissue landmarks Sella and Nasion were identified and recorded. A ten centimeter line was constructed on the pre surgical radiograph seven degrees below the sella nasion line with its origin at Sella. The location of subsequent landmarks was performed with the film orientated to SN-7 line. (Figure 3.1)

Points condylion (Co), menton (Me), and Downs point B were transferred via a template from the presurgical film to subsequent films to maintain the relative position of extremal points.

For films where either a surgical wafer was in position or where it was obvious that the teeth were not in occlusion the radiographs were corrected by rotation the mandible about the hinge axis until the incisors contacted.

The acetate tracings were then digitised on a *Hewlett Packard 9874A* digitiser configured to an *Apple IIe* computer. The software 'Cephs System' developed for cephalometric research by Brown (1996 personal communication) was programmed to record and transform these digitised points into cartesian co-ordinates relative to the SN-7 line with the origin at Sella. Data was transformed automatically by the computer and the magnification of either 8.8% or 9.1% was compensated.

All tracings and digitising was carried out by the one operator in a number of sittings.

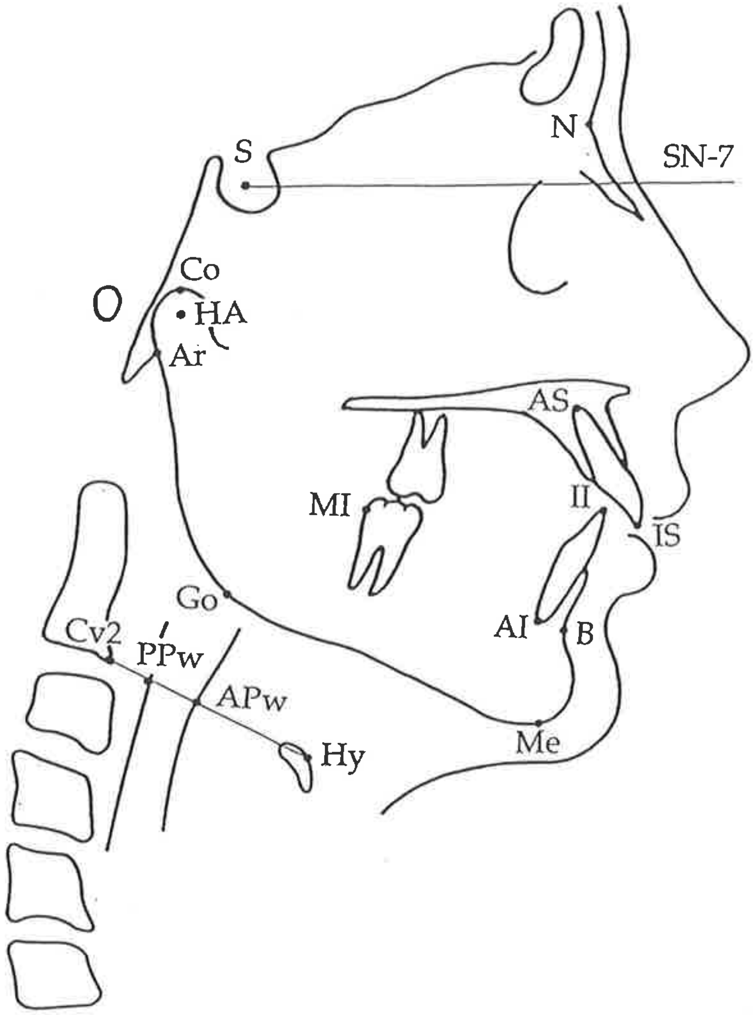
8.5 REFERENCE POINTS AND LINES

Reference points and reference lines (Figures 8.4 and 8.5) throughout the text were selected from the thesis as formulated by Hing (1989) and Ching (1995) which were derived from the Adelaide Oral and Maxillofacial Surgery Unit handbook (1983) and from the *Quick Ceph*™ manual (1986). These followed standardised cephalometric points from the literature. A number of points and variables have been amended to suit the requirements of the study. Cephalometric points which relied on radiographic structures which were not in the mid sagittal plane (condylion, hinge axis, lower molar crown and gonion) were taken as the midpoint where the two images did not coincide.

8.5.1 Hard and soft tissue points (Figure 8.4)

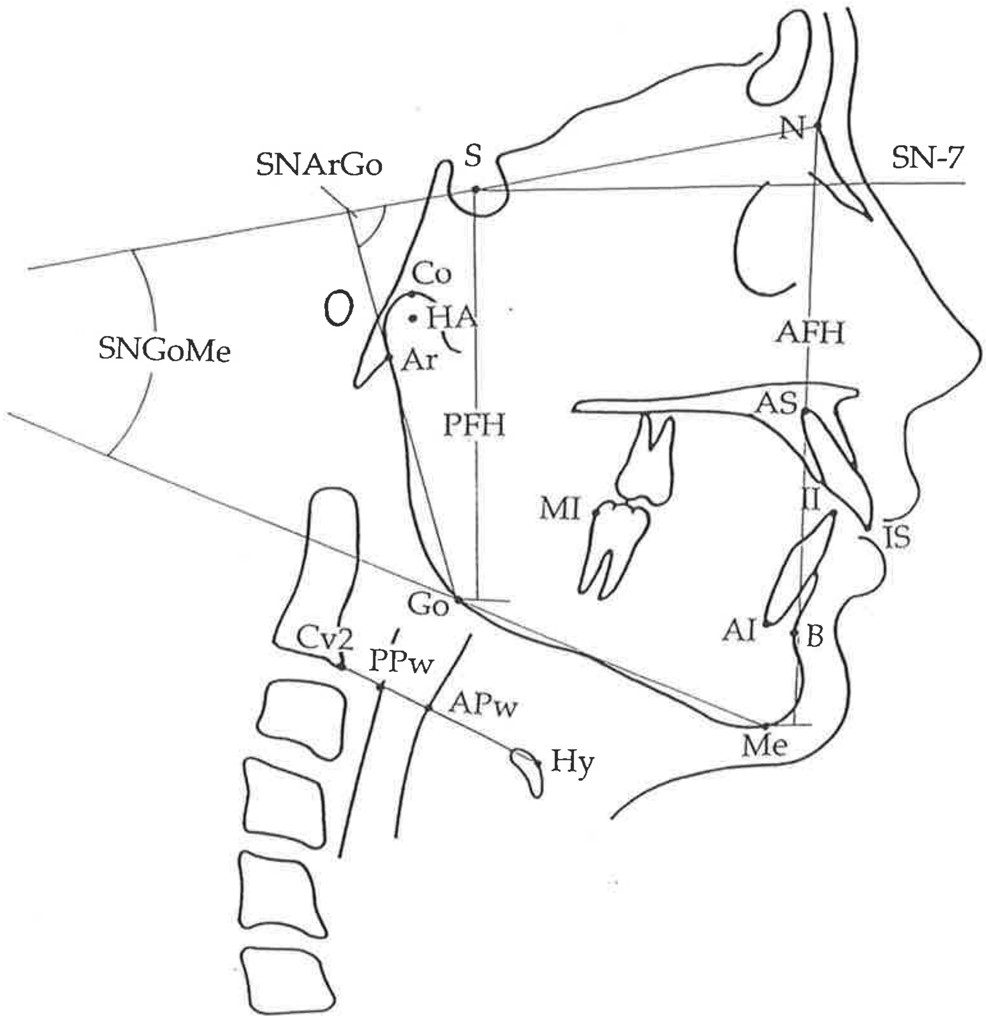
Sella (S): The centre of the pituitary fossa of the sphenoid bone determined by inspection (van der Linden, 1971; Vincent and West, 1987).

Figure 8.4 **Hard and soft tissue points listed in order of digitising sequence (modified from Hing (1989) and Ching (1995))**



1.	S	Sella
2.	N	Nasion
3.	Co	Condylion
4.	HA	Hinge axis
5	Ar	Articulare
6	Go	Gonion
7.	Me	Menton
8.	B	Down's Point B or supramentale
9.	II	Lower incisal edge
10.	AI	Lower incisal apex
11.	IS	Upper incisal edge
12.	AS	Upper incisal apex
13.	MI	Lower molar crown
14.	Hy	Hyoid
15.	AP	Anterior pharyngeal wall
16.	PP	Posterior pharyngeal wall
17.	Cv2	Cervical vertebrae 2

Figure 8.5 **Angular and linear variables used to evaluate dentoskeletal changes following mandibular advancement osteotomy**



Linear variables
Anterior facial height (AFH)
Posterior facial height (PFH)
Condylar displacement horizontal (SHAx)
Condylar displacement vertical (SHAy)
Point B horizontal (Bx)
Point B vertical (By)
Overjet
Overbite
Lower molar point horizontal (MIx)
Lower molar point vertical (MIy)
Hy point horizontal (Hyx)
Hy point vertical (Hyy)
Pharyngeal depth horizontal [AP-PP (x)]
Pharyngeal depth vertical [AP-PP (y)]

Angular variables
Mandibular plane angle (SNGoMe)
SNB
Gonial angle (ArGoMe)
Ramal angle (SNArGo)
Upper incisor angle
Interincisal angle
Lower incisal angle

Nasion (N): The most anterior point of the frontonasal suture (Brown, 1973).

Condylion (Co): The most superior point on the head of the condyle (Tracy and Savara, 1966; Sekiguchi and Savara, 1972; Brown, 1973; Lake et al. 1981; McNamara, 1984; Smith et al. 1985). Several authors, notably Björk and Palling (1954) have defined condylion as the most supero-posterior point on the head of the condyle. It is determined as the point of tangency to a perpendicular construction line to the anterior and posterior borders of the condylar head. Condylion, therefore, is located as the most superior axial point of the condylar head rather than as the most superior point on the condyle (Riolo et al. 1974).

Hinge axis (HA) or condyle: Centre of the condylar head determined by inspection (Blaseio, 1986). Kohn (1978) defined the point condyle as the centre of the head of the condyloid process.

Articulare (Ar): The point at the junction of the contour of the external cranial base and the dorsal contour of the condylar processes projected in the midsagittal plane (Wei, 1965; Brown, 1973).

Gonion (Go): The point of intersection of the line tangent to the lower border and a line through articulare and the posterior border of the ramus (Kelsey, 1968).

Menton (Me): The most inferior point on the symphyseal outline (Riolo et al. 1974).

Pogonion (Pg): The most anterior point on the contour of the bony chin relative to a perpendicular to SN-7 plane (Riolo et al. 1974).

Down's Point B or supramentale (B): The deepest point in the midsagittal plane between infradentale and pogonion, usually anterior to and slightly below the apices of the mandibular incisors (Burstone, 1978). According to Moyers (1987) Point B cannot be determined if the chin profile is flat.

Lower incisal apex (AI): The root tip of the mandibular central incisor (Riolo et al. 1974).

Lower incisal edge (II): The incisal tip of the mandibular central incisor (Riolo et al. 1974).

Upper incisal edge (IS): The incisal tip of the maxillary central incisor (Riolo et al. 1974).

Upper incisal apex (AS): The root tip of the maxillary central incisor (Riolo et al. 1974).

Lower molar crown (MI): The distal contact (height of contour) of the mandibular first molar relative to the occlusal plane (Riolo et al. 1974).

Hyoid (Hy): The most superoanterior point on the body of the hyoid bone (Athanisou et al. 1991).

Cervical vertebrae 2 (Cv2): The most anteroinferior point on the corpus of the second cervical vertebrae (Athanisou et al. 1991).

Anterior pharyngeal wall (AP): The anterior pharyngeal wall along the line intersecting the most anteroinferior point of the corpus on the second cervical vertebrae and the point hyoid (Athanisou et al. 1991).

Posterior pharyngeal wall (PP): The posterior pharyngeal wall along the line intersecting the most anteroinferior point of the corpus on the second cervical vertebrae and the point hyoid (Athanisou et al. 1991).

8.5.2 Cephalometric lines

Nasion-sella line (NSL): A line passing through nasion and sella (Solow, 1966).

Sella-nasion-7 (SN-7): A line constructed by drawing a line 7° to SN plane with its origin at sella as described by Marcotte (1981). Burstone (1978) refers to SN-7 as a surrogate Frankfort plane with its origin at nasion.

Mandibular line or plane (ML): A line drawn through menton and gonion. This line has also been defined as the tangent to the lower border of the mandible or a line joining gonion and gnathion (Salzmann, 1960).

8.5.3 Calculation of linear and angular variables

The variables were selected from those reported by Kohn (1978), Lake et al. (1981) and Athanasiou (1991). A second program by Brown (personal communication, 1996), *Ceph Scorer*, was used to compute all measurements. A feature within the program allows a variety of measurements to be performed between any of the digitised points. fourteen linear and seven angular variables (Figure 8.5) were calculated from the digitised points and stored as disk files. The files were transferred from an *Apple IIGS* computer to an *Apple Macintosh 6200/75* computer via *Microsoft Excell (version 4)* for final editing and statistical evaluation.

Linear variables

Anterior facial height (AFH): The distance between menton and nasion perpendicular to the SN-7 line.

Posterior facial height (PFH): The distance between gonion and sella perpendicular to the SN-7 line.

Condylar displacement horizontal (S-HAx): The horizontal distance between sella turcica and hinge axis perpendicular to the SN-7 line.

Condylar displacement vertical (S-HAy): The vertical distance between sella turcica and hinge axis perpendicular to the SN-7 line.

Point B horizontal (Bx): The horizontal distance between Down's Point B and a line drawn perpendicular to SN-7 line passing through Sella tursica.

Point B vertical (By): The vertical distance between Down's Point B and the SN-7 line.

Overjet (OJ): The distance between IS and II measured parallel to the SN-7 line.

Overbite (OB): The distance between IS and II measured perpendicular to SN-7 line

Hy point horizontal (Hyx): The horizontal distance between the most superoanterior point of the hyoid bone and a line drawn perpendicular to SN-7 line passing through Sella tursica.

Hy point vertical (Hyy): The vertical distance between the most superoanterior point of the hyoid bone and SN-7 line.

Lower molar horizontal (MIx): The distance from MI to Sella parallel to the SN-7 line.

Lower molar vertical (MIy): The distance from MI to Sella perpendicular to the SN-7 line.

Pharyngeal depth [AP-PP (x)]: The distance between the anterior pharyngeal wall and the posterior pharyngeal wall measured in the horizontal direction between the hyoid point and the cervical vertebrae 2 point.

Pharyngeal depth [AP-PP (y)]: The distance between the anterior pharyngeal wall and the posterior pharyngeal wall measured in the vertical direction between the hyoid point and the cervical vertebrae 2 point.

Angular variables

Mandibular plane angle (SNGoMe): The angle formed between nasion-sella line and the mandibular line.

SNB: The angle formed between nasion-sella line and a line drawn through nasion and Down's Point B.

Gonial angle (ArGoMe): The angle formed by a line tangent to the mandibular ramus and the mandibular plane.

Ramal angle (SNArGo): The angle formed between nasion-sella line and the line Ar-Go.

Upper incisor angle (Mx1-SN7): The angle between SN7 and a line drawn through IS and AS.

Interincisal angle (IIA): The angle between the line IS-AS and the line II-AI.

Lower incisor angle (IMPA): the angle between the mandibular line and the line II-AI.

8.6 STATISTICAL ANALYSIS

Each variable within the four groups was assessed by the mean value, standard error and minimum and maximum value using *Statview SE 1.03 (Abacus Concepts Inc., 1988).* The differences between various time periods for the 22 variables were calculated by *Statview SE.,* The Student's *t*-test for paired and unpaired values was used to determine the significance of differences for each variable. (Table 8.2)

Table 8.2 Statistical analysis of mandibular relapse following mandibular advancement.

$\bar{x}$	Mean	$\frac{\Sigma x}{N}$
se	Standard error of the mean	$\frac{s}{\sqrt{N}}$
r	Correlation coefficient	$\frac{\Sigma (x-\bar{x})(y-\bar{y})}{\Sigma (x-x)^2 (y-y)^2}$
t	Student's unpaired t-test	

$$\frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\dfrac{\left[\Sigma(x_1)^2 - \dfrac{\Sigma(x_1)^2}{N_1}\right] + \left[\Sigma(x_2)^2 - \dfrac{\Sigma(x_2)^2}{N_2}\right]}{{}^{2}\quad N_1 + N_2 - 2} * \left[\dfrac{N_1 + N_2}{N_1 N_2}\right]}}$$

where	N	=	number of determinations
	s	=	standard deviation
	x, y	=	observed scores
	x_1	=	mean of the group 1 observations
	x_2	=	mean of the group 2 observations

CHAPTER 9

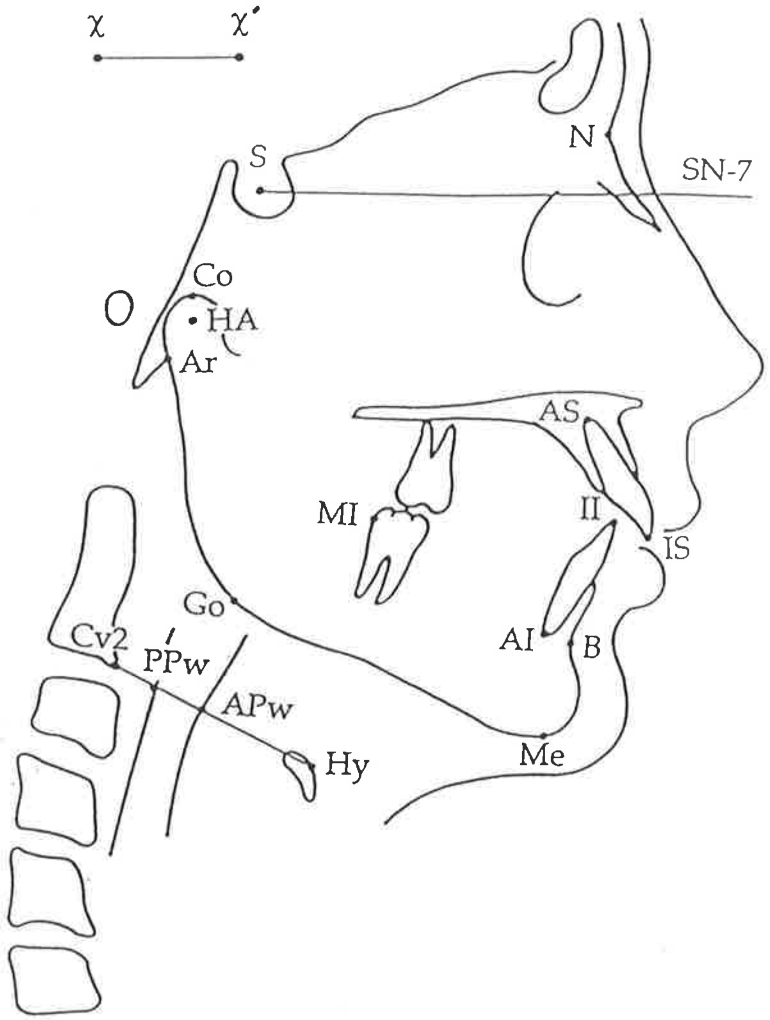
ERRORS OF THE METHOD

9.1 MATERIALS AND METHODS

To establish the validity of results in this study, an assessment of the magnitude of cephalometric errors was necessary, the method used was that described by Hing (1989) and also by Ching (1995). The magnitude of error associated with tracing, superimposition and digitising was assessed by a series of double determinations for ten cephalograms from three cases. These were randomly selected from the radiographic files of this current study.

Repeat tracing, superimposition and digitising were separated by one week and re-recorded by one observer. Tracings were orientated to the SN-7 line on the digitiser tablet and secured with cellulose tape. Alphanumeric data relating tape details and magnification compensation were entered. Magnification of 8.8% or 9.1% (Farrer, 1984) was not corrected. Twenty four tissue points and two fiducial points (x and x′) were digitised on a *Hewlett Packard* 987A digitiser configured to an *Apple IIe* computer. (Figure 9.1) Each nominated point was centrally aligned in the large window cross-hair cursor and registered by depressing a perimeter button. Data was transformed automatically by the computer and saved to disk for editing. The cephalometric software program developed by Professor Tasman Brown, The University of Adelaide, computes transformations of the cartesian coordinates relative to a nominated reference line. The line formed by x-x′ served as the line of reference. The computer was also programmed to perform superimpositions using the first fiducial point (x) as the point

Figure 9.1 Hard and soft tissue points listed in order of digitising sequence (modified from Hing, 1989 and Ching , 1995))



1.	x	fiducial point 1	11.	AI	Lower incisal apex
2.	x'	fiducial point 2	12.	II	Lower incisal edge
3.	S	Sella	13.	IS	Upper incisal edge
4.	N	Nasion	14.	AS	Upper incisal apex
5.	Co	Condylion	15.	MI	Lower molar crown
6.	HA	Hinge axis	16.	Hy	Hyoid
7.	Ar	Articulare	17.	AP	Anterior pharyngeal wall
8.	Go	Gonion	18.	PP	Posterior pharyngeal wall
9.	Me	Menton	19.	Cv2	Cervical vertebrae 2
10.	B	Down's Point B or supramentale			

of registration. Error associated with the digitising equipment has been critically assessed by Farrer (1984). The total error from the *Hewlett Packard* digitiser was <0.01 mm under normal operating conditions.

Scattergrams were produced to illustrate the reproducibility of each point using the method described by Broach et al. (1981). The first reading for each point was arbitrarily assigned as origin. The individual points on the scattergram represented the difference between the first and second cephalogram indicating the dispersion of the location errors.

The differences between the first and second determination were expressed as the mean difference (M_{diff}), the standard error of the mean difference E (M_{diff}) and the standard deviation of a single determination (S error) The Student's *t*-test for paired values was used to assess whether the differences differed significantly from zero at the 5% (t=2.262) and 1% (t=3.250) levels for 9 degrees of freedom. Table 9.1 lists the respective formulae.

Table 9.1 Statistical analysis of the experimental error

M_{diff}	Mean difference between two determinations	$\frac{\Sigma_{diff}}{N}$
$E(M_{diff})$	Standard error of the mean difference	$\frac{S_{diff}}{\sqrt{N}}$
S (error)	Standard deviation of a single determination (Dahlbert, 1940)	$\sqrt{\frac{\Sigma_{diff}^2}{2N}}$
t value	Student's paired t-test	$\frac{M_{diff}}{E(M_{diff})}$

where diff = difference between two determinations

N = number of double determinations

2N = number of single determinations

CHAPTER 10

EVALUATION OF POST SURGICAL NEUROSENSORY FUNCTION

10.1 INTRODUCTION

Inferior alveolar nerve function was assessed both subjectively by the patient and objectively by a single clinical assistant who was blind to the surgical procedure which the patient had received. The patient was asked if the sensation of their lower lip or chin felt different at the time of examination compared with how it felt immediately preoperatively? A yes or no answer was recorded. If the patient answered yes, then they were asked if the change was bilateral or unilateral and if so which side was affected.

The objective neurosensory testing was both mechanoceptive and nociceptive. The mechanoceptive component consisted of two-point discrimination and static light touch. The nociceptive component consisted of pinprick testing.

As advocated by Robinson et al (1992) the testing was carried out in a quiet room with both the patient and examiner relaxed.

10.2 MECHANOCEPTIVE TESTING

10.2.1 Static light touch

The method advocated by Robinson et al (1992) was used. A 2 cm length of 3-0 Prolene suture (Ethicon Inc.) was glued to a perspex rod and applied to the skin and vermillion border of the lower lip over the distribution of the mental nerve. The patient had their eyes closed and was asked to indicate the detection of a stimulus by raising a finger. The suture was applied randomly five times per side, a positive result was recorded if the patient correctly reported all five stimuli.

10.2.2 Two point discrimination

The method described by Robinson et al (1992) was employed, a ten sided acrylic disc was constructed by the Maxillofacial Prosthetic Laboratory Technicians, part of the Oral and Maxillofacial Surgery Unit. The disc was constructed as specified by Robinson et al with pairs of blunt wires blunt wires arranged around the edges of the disc with separations ranging from 2 - 20 mm. The wires were drawn down the skin surface, maintaining as constant a pressure as possible, starting from a level approximately 5 mm below the vermillion border of the lower lip and finishing at about the level of the lower border of the mandible.. The most medial wire was kept at least 5 mm from the midline. The patients were asked to say whether they felt one or two stimuli. The minimum distance at which they reported two was recorded.

10.3 NOCICEPTIVE TESTING

Pin prick

For this test a 22 guage needle was applied gently to the skin of the lower lip and chin with not enough force to draw blood. A new sterile needle was used for every patient. As with light touch the needle was applied five times to different locations within the area of distribution of the mental nerve, per side. The patient had their eyes closed and a positive result required every stimulus to be correctly identified.

IV

RESULTS

CHAPTER 11

RESULTS: EARLY, INTERMEDIATE AND LONG TERM DENTOSKELETAL EFFECTS FOLLOWING MANDIBULAR ADVANCEMENT

11.1 STUDY POPULATION

Table 11.1 Surgical procedures.

PROCEDURE	NUMBER OF PATIENTS
Intraoral inverted 'L'	9
Intraoral inverted 'L' + genioplasty	5
Extraoral inv. 'L' + genioplasty + LeFort I	4
Bilateral sagittal split osteotomy (B.S.S.O)	11
B.S.S.O + genioplasty	4

The records were assigned to one of the following groups:

I. Intraoral inverted 'L' osteotomies (n=14)

II. Bilateral sagittal split osteotomy (n=15)

III Exraoral inverted 'L' + genioplasty + LeFort I osteotomy (n=4)

The ages of the patients at the time of surgery was calculated to the nearest month and expressed in years. (Table 11.2-4)

Table 11.2 Group I age at time of surgery (years).

Sex	Number	Mean age (years)	Standard deviation	Min.	Max.	Range
Males	6	16.7	1.5	14.7	18.9	4.2
Females	8	20.1	4.9	15.4	30.4	15
M+F	14	18.6	4.1	14.7	30.4	15.7

Table 11.3 Group II age at time of surgery (years).

Sex	Number	Mean age (years)	Standard deviation	Min.	Max.	Range
Males	5	15.3	1.6	14.3	18.2	3.9
Females	10	21.0	7.2	14.5	34.3	19.8
M+F	15	19.1	6.4	14.3	34.3	20.0

Table 11.4 Group III age at time of surgery (years).

Sex	Number	Mean age (years)	Standard deviation	Min.	Max.	Range
Females	4	25.1	17.2	16.3	51.0	34.7

11. 2 COMPLICATIONS

No serious intraoperative complications were encountered in any of the groups. The intraoral inverted 'L' osteotomies were a more demanding procedure and the duration of the procedure was on average one hour more than that of the bilateral sagittal split osteotomy. There were no patients who experienced haemorrhage requiring transfusion in Group I or Group II. All patients who underwent two jaw surgery donated two autologous units of blood and all received at least one of these units back.

One patient in Group I experienced a fracture of the proximal segment intraoperatively due to placement of the horizontal cut too high, this necessitated a further osteotomy cut at a lower level with no untoward events, this patient experienced no obvious relapse of point B in either the horizontal or vertical direction. Two patients in Group II experienced unfavourable splits, involving the buccal plate, these could be repaired by using an extra screw in each case to secure the fragment.

One patient from Group I exhibited movement of the bone graft from where it was placed. This was noticed at the time of the first post operative radiograph as a spicule of bone projecting below the lower border. It could be palpated initially but disappeared with remodelling after several weeks and caused no adverse effects.

Post operatively one patient from Group III experienced marked unilateral facial nerve palsy affecting all branches of the nerve. This resolved spontaneously within three months.

Postoperative infection occurred in two patients in Group I and one in Group II. One of these patients from Group I required surgical drainage by a second operation and the other two were treated with a course of oral antibiotics. All cases resolved without any residual problems.

Three patients complained of being able to palpate the inferior plate over the angle of the mandible and were concerned by this although it was not painful. They were offered removal of this and all accepted, accordingly this was performed under general anaesthetics via the intraoral route and using a trans buccal trocar. Removal proved difficult due to bone growth around the plates and screws, in one case parts of two screws had to be left as they were firmly integrated into the bone. No screws or plates were loose in any of the three patients.

11.3 ANALYSIS OF VARIABLES BY GROUPS

11.3.1 Mandibular movements

11.3.1.1 Changes in the horizontal position of point B

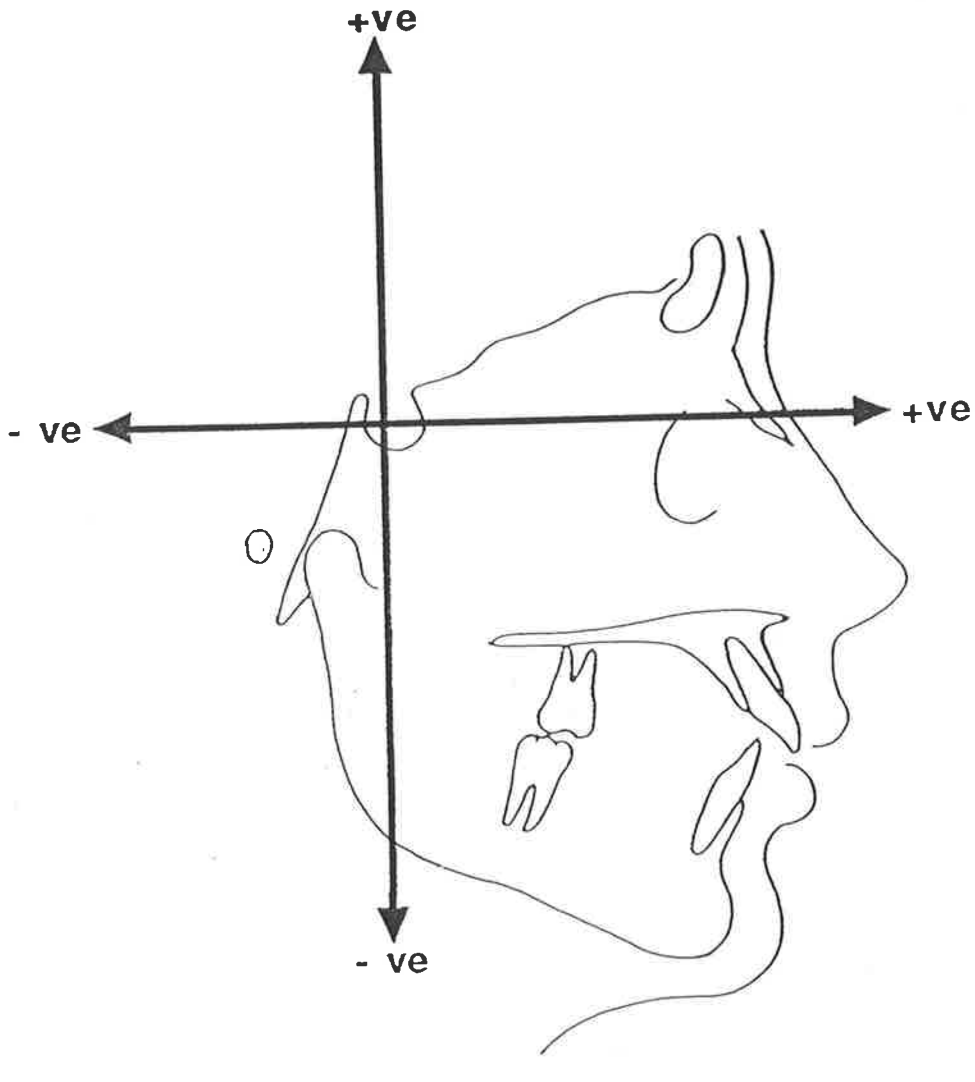
The magnitude of surgical advancement (T1-T2) and subsequent changes are shown in Table 11.5. The digitiser has been programmed to use cartesian co-ordinates with the origin at Sella and the x axis on the SN-7 line, thus either positive or negative signs are allocated to the values to indicate the direction of the movements. (Figure 11.1) Varying amounts of relapse are noted over subsequent time periods, the mean values of which are less than or equal to zero, however some individuals show positive values. The positive values indicate that point B has moved anteriorly. Those patients who exhibited anterior movement invariably also showed a superior movement of point B.

Table 11.5 Horizontal advancement B Point (T1-T2 in mm) and relapse pattern (T2-T7) for inverted 'L' and B.S.S.O. groups.

GROUP	INV. L			BSSO		
Patients	M: 6	F: 8	M + F:14	M: 5	F: 10	M+F: 15
T1-T2 (mean±S.E.)	6.0	5.2	5.5 (±0.9)	9.3	5.0	6.4(±0.8)
t-value	3.13*	6.50**	6.20**	6.00**	7.50**	7.60**
Min. (mm)	1.2	2.8	1.2	5.1	1.2	1.2
Max. (mm)	14.4	9.1	14.4	12.7	7.2	12.7
Patients	M: 2	F: 4	M+F: 6	M: 2	F: 2	M+F: 4
T2-T3 (mean±S.E.)	-0.5	-2.4	-1.8(±1.1)	-0.7	-0.2	-0.5(±1.4)
t-value	-0.30	-1.56	-1.56	-0.37	-0.08	-0.33
Min. (mm)	-2.3	-5.9	-6.0	-2.6	-3.2	-3.2
Max. (mm)	1.25	1.5	1.5	1.2	2.7	2.7
Patients	M: 1	F: 4	M+F: 5	M: 2	F: 1	M+F: 3
T2-T4 (mean±S.E.)	-2.4	-3.1	-2.9(±0.7)	-1.7	-2.2	-1.8(±0.8)
t-value		-3.35*	-4.07*	-1.30		-4.07
Min. (mm)		-5.0	-5.0	-3.0		-3.0
Max. (mm)		-1.1	-1.1	-0.3		-0.3
Patients	M: 2	F: 3	M+F: 5	M: 4	F: 3	M+F: 7
T2-T5 (mean±S.E.)	-1.4	-2.7	-2.2(±1.4)	-1.4	-0.9	-1.1(±0.8)
t-value	-0.40	-1.62	-1.55	-1.57	-0.49	-1.41
Min. (mm)	-4.7	-5.8	-5.8	-2.7	-4.4	-4.4
Max. (mm)	1.8	-0.2	1.8	1.1	1.1	1.1
Patients	M: 3	F: 5	M+F: 8	M: 1	F: 4	M+F: 5
T2-T6 (mean±S.E.)	0.0	-2.1	-1.3(±1.0)	-0.7	1.7	1.2(±1.4)
t-value	-0.00	-1.54	-1.32		0.99	0.86
Min. (mm)	-1.58	-7.0	-7.0		-2.6	-2.6
Max. (mm)	2.52	.57	2.5		5.4	5.4
Patients	M: 2	F: 1	M+F: 3	M: 2	F: 3	M+F: 5
T2-T7 (mean±S.E.)	-1.4	0.4	-0.8(±1.0)	-0.4	-1.0	-0.8(±1.2)
t-value	-1.01		-0.78	-0.93	-0.37	-0.50
Min. (mm)	-2.8		-2.8	-0.8	-4.7	-4.7
Max. (mm)	0.0		0.4	0.0	3.6	3.6

* =P< 0.05
** =p< 0.005

Figure 11.1 Axis of cartesian co-ordinates used in the study relative to craniofacial structures



The magnitude of the surgical shift was compared by Group, the results are displayed in Table 11.6.

Table 11.6 Comparison of surgical advancement at point B (x) between groups.

GROUP	t- VALUE	PROBABILITY
I-II	-0.28	0.785
I-III	3.12	0.007
II-III	3.4	0.004
(I+II)-III	3.66	0.001

Group I: Intraoral inverted 'L' osteotomy (n = 14)

The mean mandibular advancement at B point was 5.5 mm with a range of 1.2 to 14.4 mm.

The six male subjects had a mean mandibular advancement of 6.0 mm with a range of 1.2 to 14.4 mm. The two males who were included in the short term period (T3) had a statistically insignificant loss of 0.5 mm. The eight females were advanced an average of 5.2 mm with a range of 2.8 to 9.1 mm. The four females who were included in the short term period showed a mean loss of 2.4 mm this was statistically insignificant.

Changes occurring from the first post operative radiograph until the intermediate time period consisted of the sub groups T2-T4 and T2-T5. Only one male was represented in sub group T2- T4 and he showed a loss of 2.4 mm this was not statistically significant. Four females were included in the T2-T4 subgroup and they exhibited a statistically significant mean loss of 3.1 mm. Two males and three females were present in the T2-T5 subgroup and they showed a statistically insignificant mean loss of 1.4 and 2.7 mm respectively.

Of particular note is a female subject who was 17 years and four months old at the time 4 of surgery, she underwent mandibular advancement of 5.0 mm at point B. By two months post surgery she had relapsed posteriorly 5.8 mm. A radiograph taken four months postoperatively revealed she had continued to relapse and had moved posteriorly a total of 7.0 mm in the postoperative period. The vertical movements at point B for this patient showed an inferior movement with surgery of 1.3 mm and a further inferior movement of 0.7 mm by 4 months post surgery. When her radiographs were examined closely it is apparent that her ramal height has decreased in the post surgically period as seen by the distance from the bone plates to the SN-7 line.

Changes occurring from the first post operative radiograph until the long term period are shown in the sub groups T2-T6 and T2-T7, no changes in these time periods are statistically significant. Three males were included in the subgroup T2-T6 and showed no mean change while five females exhibited a mean loss of 2.1 mm. Two males and one female were included in the subgroup T2-T7 the males showed a mean loss of 1.4 mm while the female showed a loss of 0.4 mm.

Initial examination of the data consisted of analysis of the horizontal movement of Point B and subsequent changes over the short, medium and long term. The results are tabulated by the surgical procedure and grouped by sex. Analysis of the data by students t test revealed that there were no statistically significant sex differences within Groups I and II (Group III consisted solely of females). For this reason the males and females were combined for further analysis. Group III was found to be statistically significantly different to the other groups when the advancement of point B was assessed for this reason this group was kept separate.

Group II Bilateral sagittal split osteotomy (N = 15)

The mean mandibular advancement at B point was 6.4 mm with a range of 1.2 to 12.7 mm. As with Group I varying amounts of relapse are noted over subsequent time periods, however with this group with the exception of the surgical shifts none of the changes are statistically significant.

Two males and two females were measured over the short term (T2-T3), they showed a mean loss of 0.7 and 0.2 mm respectively.

Changes occurring from the first post operative radiograph until the intermediate time period again consisted of the sub groups T2-T4 and T2-T5. Two males and one female were included in the subgroup T2-T4, they showed a mean loss of 1.7 and 2.2 mm respectively. Included in the subgroup T2-T5 are four males and three females exhibiting a mean loss of 1.4 and 0.9 mm respectively.

Changes occurring from the first post operative radiograph until the long term period are again shown in the sub groups T2-T6 and T2-T7. The T2-T6 subgroup consists of one male and four females who exhibited a mean loss of 0.7 and 1.7 mm respectively. The T2-T7 subgroup consists of two males and three females who exhibited a mean loss of 0.4 and 1.0 mm respectively.

Of note is a 21 year old female who showed an anterior movement of point B of 5.4 mm, however this can be accounted for by mandibular changes due to vertical changes as point B was found to move superiorly 5.0 mm in the same period of time.

The horizontal changes with time for Group I and II were investigated to ascertain if relapse was occurring in any particular pattern. No obvious pattern was apparent possibly due to the small sample sizes. In an effort to increase the sample sizes the data was then analysed by comparing the T2 radiograph with the most recent radiograph (TL), the results are summarised in Table 11.7

Group III Extraoral inverted 'L' / Le Fort I (n=4)

This group consisted of only four subjects in total, all females. Data was analysed by comparing the surgical advancement (T1-T2) and the relapse between T2 and TL. The results are summarised in Table 11.8 and TL by group in Table 11.9.

There was no statistical difference for TL between Group I and II (males + females combined).

Table 11.7 Horizontal advancement (T1-T2) and relapse pattern (T2-TL) for inverted 'L' and B.S.S.O. groups.

GROUP	INV. L			BSSO		
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F: 10**	**M+F: 15**
T1-T2 (mean±S.E.)	6.0	5.2	5.5(±0.9)	9.3	5.0	6.4(±0.8)
t-value	3.13*	6.50**	6.20**	6.00**	7.50**	7.60**
Min. (mm)	1.2	2.8	1.2	5.1	1.2	1.2
Max. (mm)	14.4	9.1	14.4	12.7	7.2	12.7
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F:10**	**M+F: 15**
T2-TL (mean±S.E.)	-0.3	-1.7	-1.1(±0.7)	-1.1	0.47	-0.1(±0.8)
t-value	-0.34	-1.62	-1.6	-1.50	0.43	-0.09
Min. (mm)	-2.8	-7.0	-7.0	-2.7	-4.7	-4.7
Max. (mm)	2.5	1.8	2.5	1.1	5.4	5.4

* =p< 0.05

** = p<0.005

Table 11.8 Horizontal changes B Point- (T1-T2) and relapse pattern (T2-TL) for Extraoral inverted 'L' + Le Fort 1 group.

GROUP	III (EO INV. L +LF1)
Patients	**F: 4**
T1-T2 (mean±S.E.)	12.4(±1.8)
t-value	7.08**
Min. (mm)	8.52
Max. (mm)	15.57
Patients	**F: 4**
T2-TL (mean±S.E.)	-5.4(±0.7)
t-value	-6.35**
Min. (mm)	-7.3
Max. (mm)	-3.3

* =p< 0.05

** =p< 0.005

Table 11.9 Time (in weeks post operative) of TL by group

Time postop.	Group I Males	Group I Females	Group I M.+ F	Group II Males	Group II Females	Group II M + F	GroupIII
Mean	82	67	74.5	108.4	87.4	97.9	95.5
max	150	126	150	212	208	212	208
min	7	16	7	41	11	11	40

11.3.1.2 Point B vertical changes

Group I Intraoral Inverted 'L' osteotomy (n=14; Table 11.10)

Point B moved inferiorly a statistically significant (p< 0.005) distance of -3.3 mm range -6.4 to -0.3 mm with surgery and relapsed superiorly a statistically insignificant distance of 0.4 mm range -3.4 to 3.1 mm from T2-TL.

There was little difference between the sexes, the males moving -3.1 mm range-6.4 to -0.3 mm inferiorly and females -3.5 mm range -5.1 to -1.3 mm with surgery and relapsing 0.3 mm range -0.8 to 1.3 mm; and 0.5 mm range -3.4 to 3.1 mm respectively.

Group II Bilateral sagittal split osteotomy (n=15 Table 11.10)

Point B moved inferiorly a statistically significant (p< 0.05) distance of - 2.8 mm range -5.9 to 0.7 mm with surgery and moved further inferiorly a statistically insignificant distance of -0.7 mm range -5.9 to 5.0 mm from T2-TL.

There was no difference between the mean values of the sexes, both moving -2.8 mm inferiorly with surgery and relapsing 0.7 mm superiorly. The range for the surgical shift of the males and females were -5.2 to 0.3 mm and -5.9 to 0.7 mm respectively. The range for the value T2-TL of the males and females were -1.8 to 1.0 mm and -5.8 to 5.0 mm respectively.

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.11)

Point B moved a statistically insignificant distance of 1.3 mm range -1.2 to 3.9 mm superiorly and moved inferiorly a statistically insignificant distance of (-) 0.1 mm range -1.6 to 1.7 from T2-TL.

Table 11.10 Vertical change in B point (T1-T2) and relapse pattern (T2-TL) for inverted 'L' and B.S.S.O. groups.

GROUP	INV. L			BSSO		
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F: 10**	**M+F: 15**
T1-T2 (mean mm)	-3.1	-3.5	-3.3	-2.8	-2.8	-2.7
t-value	-3.62*	-8.49**	-7.96**	-2.40*	-4.20**	-4.8**
Min. (mm)	-6.4	-5.1	-6.4	-5.2	-5.9	-5.9
Max. (mm)	-0.3	-1.3	-0.3	0.3	0.7	0.7
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F:10**	**M+F: 15**
T2-TL(mean mm)	0.3	0.5	0.4	-0.7	-0.7	-0.7
t-value	1.04	0.62	0.85	-1.36	0.67	-1.02
Min. (mm)	-0.8	-3.4	-3.4	-1.8	-5.8	-5.8
Max. (mm)	1.3	3.1	3.1	1.0	5.0	5.0

* =p< 0.05

** =p< 0.005

Table 11.11 Vertical movement of B point (T1-T2) and relapse pattern (T2-TL) for inverted 'L' + Le Fort 1 group.

GROUP	EO INV. L +LF1
Patients	**F: 4**
T1-T2 (mean mm)	1.3
t-value	1.06
Min. (mm)	-1.2
Max. (mm)	3.9
Patients	**F: 4**
T2-TL(mean mm)	-0.1
t-value	-0.30
Min. (mm)	-1.6
Max. (mm)	0.7

* =p< 0.05

** =p< 0.005

11.3.1.3 Angle SNB

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.12)

The angle SNB increased a mean 3.2° with surgery with a range -0.1° to 8.0°. This angle decreased by (-)0.8° range -3.6° to 1.0° from T2-TL . Both the value of the surgical shift and the relapse are statistically significant (p< 0.005). The male subjects increased a mean of 3.4° with surgery and lost a statistically insignificant 0.5° from T2-TL. The females gained 3.1° with surgery and lost a statistically significant (p< 0.05) 1.1° from T2-TL .

Group II Bilateral sagittal split osteotomy (n=15 Table 11.12)

The angle SNB increased a mean 4.2° with surgery with a range 2.1° to 6.9°. This angle decreased by (-)0.6° range -1.75° to 2.6° from T2-TL . Only the value of the surgical shift was statistically significant (p< 0.005).

The male subjects increased a mean of 5.4° with surgery and lost a statistically significant 1.3° from T2-TL. The females gained 3.5° with surgery and lost a statistically insignificant 0.2° from T2-TL.

There were no statistically significant differences (p <0.05) for either surgical change or T2-TL between Groups I and II for angle SNB. (Table 11.13)

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.14)

The angle SNB increased a mean 6.6° with surgery with a range 5.1° to 8.4°. This angle decreased a mean 2.8° in the period T2-TL . Both the value of the surgical shift and relapse are statistically significant (p< 0.005).

Table 11.12 SNB Changes in degrees (T1-T2) and relapse pattern (T2-TL) for inverted 'L' and B.S.S.O. groups.

GROUP	INV. L			BSSO		
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F: 10**	**M+F: 15**
T1-T2 (mean °)	3.4	3.1	3.2	5.4	3.5	4.2
t-value	3.01*	6.4**	6.08**	6.95**	10.46**	10.36**
Min. (°)	-0.1	1.3	-0.1	3.4	2.1	2.1
Max. (°)	8.0	5.9	8	6.9	5.1	6.9
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F:10**	**M+F: 15**
T2-TL (mean °)	-0.5	1.1	-0.8	-1.3	-0.2	-0.6
t-value	-0.94	-2.08**	-2.26**	-6.2**	-0.47	-1.75
Min. (°)	-2.8	-3.6	-3.6	-1.7	-2.1	-2.1
Max. (°)	1.0	0.6	1.0	2.6	2.6	2.6

* =p< 0.05

** =p< 0.005

Table 11.13 Comparison of changes in angle SNB for Groups I and II

GROUP	t VALUE	PROBABILITY
I -II Surgical change	1.39	0.17
I-II relapse	0.56	0.58

Table 11.14 SNB Changes in degrees. (T1-T2) and relapse pattern (T2-TL) for Extraoral inverted 'L' + LeFort 1 group.

GROUP	Extraoral INV. L +LF1
Patients	**F: 4**
T1-T2 (mean °)	6.6
t-value	8.57**
Min. (°)	5.1
Max. (°)	8.4
Patients	**F: 4**
T2-TL (mean °)	-2.8
t-value	-8.90**
Min. (°)	-2.0
Max. (°)	-3.5

* =p< 0.05

** =p< 0.005

11.3.2 Proximal and distal segment alterations

11.3.2.1 Hinge axis horizontal changes (HA x)

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.15)

The hinge axis moved posteriorly a statistically insignificant (-) 0.1 mm range -3.9 to 3.6 mm. Postoperatively a further posterior shift of (-) 0.8 mm was a statistically significant distance, range -3.5 to 2.6 mm ($p < 0.05$).

Group II Bilateral sagittal split osteotomy (n=15 Table 11.15)

A surgical shift of (-)0.2 mm was measured, this and subsequent changes were not statistically significant.

Group III Extraoral inverted 'L' / LeFortI osteotomy (n=4 Table 11.16)

A posterior movement of (-)1.5 mm, range -2.5 to 0.9 mm was measured in this group due to surgery. A forward movement of 0.8 mm, range -2.4 to 3.4 mm was seen in the T2-TL period. Only the initial movement was statistically significant ($p < 0.005$).

Table 11.15 HA Horizontal changes (T1-T2) and relapse pattern (T2-TL) for inverted 'L' and B.S.S.O. groups.

GROUP	INV. L			BSSO		
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F: 10**	**M+F: 15**
T1-T2 (mean mm)	-0.1	-0.1	-0.1	0.2	-0.4	-0.2
t-value	-0.04	-0.18	-0.17	0.36	-1.72	-0.74
Min. (mm)	-1.6	-3.9	-3.9	-1.3	-1.7	-1.7
Max. (mm)	3.65	2.41	3.6	2.4	0.8	2.38
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F:10**	**M+F: 15**
T2-TL(mean mm)	-0.6	-0.9	-0.8	-0,4	0.1	0.0
t-value	-1.40	-1.40	-1.93*	-0.80	0.42	0.42
Min. (mm)	-1.5	-3.5	-3.5	-1.4	-1.1	-1.4
Max. (mm)	1.3	2.6	2.6	1.4	1.6	1.6

* =p< 0.05

** =p< 0.005

Table 11.16 HA (Horizontal changes) (T1-T2) and relapse pattern (T2-TL) for Extraoral inverted 'L' + LeFort 1 group.

GROUP	Extraoral INV. L +LF1
Patients	**F: 4**
T1-T2 (mean mm)	-1.5
t-value	-4.19**
Min. (mm)	-2.5
Max. (mm)	-0.9
Patients	**F: 4**
T2-TL (mean mm)	0.8
t-value	0.55
Min. (mm)	-2.4
Max. (mm)	3.4

* =p< 0.05

** =p< 0.005

11.3.2.2 Hinge axis vertical changes

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.17)

The hinge axis moved inferiorly a statistically insignificant (-) 0.3 mm range -3.3 to 3.1 mm. Postoperatively a further inferior shift of (-) 0.6 mm again a statistically insignificant distance, range -2.8 to 2.7 mm. The only statistically significant ($p < 0.05$) finding for this group was for males T2-TL where an inferior movement of (-)1.6 mm was seen, range -2.8 to 0.0 .

Group II Bilateral sagittal split osteotomy (n=15 Table 11.17)

The surgical shifts and subsequent changes were not statistically significant with the exception of the female T2-TL subgroup where an inferior movement of -1.0 mm range -3.5 to 1.1 mm occurred ($p < 0.05$).

Group III Extraoral inverted 'L' / LeFortI osteotomy (n=4 Table 11.18)

An inferior movement of -1.3 mm, range -2.5 to 0.0 mm was measured in this group due to surgery. A superior movement of 2.1 mm, range 0.8 to 3.8 mm was seen in the T2-TL period. Both the initial and subsequent movement was statistically significant ($p < 0.05$).

Table 11.17 HA Vertical changes (T1-T2) and relapse pattern (T2-TL) for inverted 'L' and B.S.S.O. groups.

GROUP	INV. L			BSSO		
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F: 10**	**M+F: 15**
T1-T2 (mean mm)	0.7	-1.1	-0.3	-1.6	0.2	-0.4
t-value	0.99	-1.78	-0.65	-1.6	0.61	-0.86
Min. (mm)	-1.7	-3.3	-3.3	-4.5	-1.5	-4.5
Max. (mm)	3.1	1.0	3.1	0.3	1.8	1.8
Patients	**M: 6**	**F: 8**	**M+F: 14**	**M: 5**	**F:10**	**M+F: 15**
T2-TL(mean mm)	-1.6	0.1	-0.6	0.2	-1.0	-0.6
t-value	-3.74*	0.12	-1.50	0.23	-2.10*	-1.37
Min. (mm)	-2.8	-1.9	-2.8	-2.2	-3.5	-3.5
Max. (mm)	0.0	2.7	2.7	2.7	1.1	2.7

* =p< 0.05

** =p< 0.005

Table 11.18 Hinge Axis Vertical changes (T1-T2) and relapse pattern (T2-TL) for Extraoral inverted 'L' + LeFort 1 group.

GROUP	Extraoral INV. L +LF1
Patients	**F: 4**
T1-T2 (mean mm)	-1.3
t-value	-2.49*
Min. (mm)	-2.5
Max. (mm)	0.0
Patients	**F: 4**
T2-TL (mean mm)	2.1
t-value	3.20*
Min. (mm)	0.8
Max. (mm)	3.8

* =p< 0.05

** =p< 0.005

11.3.2.3 Mandibular plane to SN (SNGoMe)

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.19)

A statistically significant ($p < 0.05$) increase of 1.9° was measured with surgery , range -2.4° to 7.4° this implies a clockwise rotation of the distal segment. A further increase of 2.1°, range -1.9° to 9° from T2-TL was measured and was also significant ($p < 0.05$).

Group II Bilateral sagittal split osteotomy (n=15 Table 11.19)

A statistically insignificant increase of 0.7° was measured with surgery, range -2.7° to 3.7°. A further increase of 0.2°, range -3.9° to 5.4° from T2-TL was measured and was also insignificant.

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.19)

A statistically significant ($p < 0.05$) decrease of (-)12.2° was measured with surgery , range -13.2° to -10.9°. A further increase of 3.5°, range 2.7° to 5.1° from T2-TL was measured and was also significant ($p < 0.05$).

Table 11.19 SNGoMe (T1-T2) and relapse pattern (T2-TL) for inverted 'L', B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups. (measurements in degrees)

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2	1.9	0.7	-12.2
t-value	2.29*	1.21	-21.57**
Min.	-2.1	-2.7	-13.2
Max.	7.4	3.7	-10.86
Patients	**14**	**15**	**4**
T2-TL	2.1	0.2	3.5
t-value	2.63*	0.3	6.72**
Min.	-1.9	-3.9	2.7
Max.	9.0	5.4	5.1

* =p< 0.05

** =p< 0.005

11.3.2.4 Anterior face height

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.20)

A statistically significant ($p < 0.005$) increase of 4.2 mm was measured with surgery , range 1.0 to 10.2 mm. A subsequent decrease of (-) 0.3 mm, range -3.6 to 4.7 mm from T2-TL was measured and was not statistically significant.

Group II Bilateral sagittal split osteotomy (n=15 Table 11.20)

A statistically significant ($p < 0.005$) increase of 3.2 mm was measured with surgery, range -1.5 to 6.9 mm. An increase of 1.4 mm, range -3.8 to 5.0 mm from T2-TL was measured and was again statistically significant ($p < 0.05$) .

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.20)

A statistically insignificant increase of 1.7 mm was measured with surgery, range -0.4 to 1.0. A subsequent decrease of -0.1, range -1.1 to 1.0 mm from T2-TL was measured but was not statistically significant.

Table 11.20 Anterior facial height (T1-T2) and relapse pattern (T2-TL) for inverted 'L', B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (mm)	4.2	3.2	1.7
t-value	6.50**	4.83**	1.41
Min. (mm)	1.0	-1.5	-0.4
Max. (mm)	10.2	6.9	5.3
Patients	**14**	**15**	**4**
T2-TL (mm)	-0.3	1.4	-0.1
t-value	-0.62	1.96*	-0.19
Min. (mm)	-3.6	-3.8	-1.1
Max. (mm)	4.7	5.0	1.0

* =p< 0.05

** =p< 0.005

11.3.2.5 Posterior face height

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.21)

A statistically insignificant increase of 0.2 mm was measured with surgery, range -4.1 to 2.6 mm. A subsequent decrease of (-) 1.3 mm, range -8.2 to 2.6 mm from T2-TL was measured and was statistically significant ($p < 0.05$).

Group II Bilateral sagittal split osteotomy (n=15 Table 11.21)

A statistically insignificant increase of 0.2 mm was measured with surgery, range -1.2 to 2.6 mm. An further increase of 0.7 mm, range -1.0 to 3.8 mm from T2-TL was measured and was statistically significant ($p < 0.005$).

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.21)

A statistically insignificant increase of 1.6 mm was measured with surgery, range 0.3 to 2.5 mm. A subsequent decrease of -3.5, range -7.7 to 0.7 mm from T2-TL was measured but was not statistically significant.

Table 11.21 Posterior facial height (T1-T2) and relapse pattern (T2-TL) for inverted 'L' , B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	14	15	4
T1-T2 (mm)	0.2	0.2	1.6
t-value	0.51	0.65	3.09
Min. (mm)	-4.1	-1.2	0.3
Max. (mm)	2.6	2.6	2.6
Patients	14	15	4
T2-TL (mm)	-1.3	0.7	-3.5
t-value	-1.89*	1.88**	-2
Min. (mm)	-8.2	-1.0	-7.7
Max. (mm)	2.6	3.8	0.7

* =p< 0.05

** =p< 0.005

11.3.2.6 MI (y) vertical

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.22)

A statistically significant ($p < 0.005$) increase of (-) 2.7 mm was measured with surgery, range -4.5 to 0.0 mm. A subsequent decrease of 0.9 mm, range -2.2 to 3.4 mm from T2-TL was measured and was statistically significant ($p < 0.05$) .

Group II Bilateral sagittal split osteotomy (n=15 Table 11.22)

A statistically significant ($p < 0.005$) increase of (-)0.3 mm was measured with surgery, range -3.0 to 3.3 mm. An further increase of 0.7 mm, range -1.0 to 3.8 mm from T2-TL was measured and was not statistically significant.

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.22)

A statistically insignificant increase of (-)1.5 mm was measured with surgery, range -3.4 to 0.0 mm. A subsequent decrease of (-)0.3, range -1.5 to 2.2 mm from T2-TL was measured but again was not statistically significant.

Table 11.22 MI (y) (T1-T2) and relapse pattern (T2-TL) for inverted 'L' , B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (mm)	-2.7	-3.6	-1.5
t-value	-9.13**	-8.60**	-1.96
Min. (mm)	-4.5	-5.6	-3.4
Max. (mm)	0.0	-1.2	0.0
Patients	**14**	**15**	**4**
T2-TL (mm)	0.9	-0.3	0.3
t-value	2.44*	-0.63	0.46
Min. (mm)	-2.2	-3.0	-1.5
Max. (mm)	3.4	3.3	2.2

* =p< 0.05

** =p< 0.005

11.3.3 Segmental interrelationships

11.3.3.1 Gonial angle (ArGoMe)

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.23)

A statistically insignificant increase of 1.7° was measured with surgery, range -7.4° to 8.4°. A further increase of 6.4°, range -1.2° to 13.8° from T2-TL was measured and was statistically significant ($p< 0.005$) .

Group II Bilateral sagittal split osteotomy (n=15 Table 11.23)

A statistically significant ($p< 0.005$) increase of 3.2° was measured with surgery, range -2.2° to 9.2°. A decrease of (-)0.1°, range -3.0° to 3.4° from T2-TL was measured and was statistically insignificant.

Group III Extraoral inverted 'L' / LeFort I osteotomy (N =4 Table 11.23)

A statistically significant ($p< 0.005$) decrease of (-)12.6° was measured with surgery, range -13.2° to -11.2°. A further decrease of (-)0.9°, range -8.6° to 7.0° from T2-TL was measured but was not statistically significant.

Table 11.24 compares the changes in the gonial angle seen with surgery and postoperatively

Table 11.23 Gonial angle (ArGoMe) (T1-T2) and relapse pattern (T2-TL) for inverted 'L' , B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups. (measurements in degrees)

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2	1.7	3.2	-12.6
t-value	1.38	4.20**	-28.31**
Min.	-7.4	-2.2	-13.2
Max.	8.4	9.2	-11.2
Patients	**14**	**15**	**4**
T2-TL	6.4	-0.1	-0.9
t-value	4.76**	-0.33	-.21
Min.	-1.2	-3.0	-8.6
Max.	13.8	3.4	7.0

* =p< 0.05

** =p< 0.005

Table 11.24 Gonial angle changes comparison between groups.

GROUP	t VALUE	PROBABILITY
I -II Surgical change	0.99	0.33
I+II- III Surgical change	7.62	0.0001
I-II Relapse	-4.77	0.0001
II-III Relapse	0.35	0.734
I-III Relapse	2.21	0.0419
I-II relapse	0.56	0.58

11.3.3.2 Ramal angle (SNArGo)

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.25)

A statistically insignificant increase of 0.1° was measured with surgery, range -3.5° to 6.7°. A further decrease of -4.3°, range -11.3° to 0.8° from T2-TL was measured and was statistically significant ($p< 0.005$) .

Group II Bilateral sagittal split osteotomy (n=15 Table 11.25)

A statistically significant ($p< 0.005$) decrease of (-) 2.5° was measured with surgery, range -6.8° to 2.9°. An increase of 0.3°, range -3.9° to 3.3° from T2-TL was measured but was not statistically significant.

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.25)

A statistically insignificant increase of 0.4° was measured with surgery, range 0.4° to 1.5°. A further increase of 4.4°, range -4.2° to 13.6° from T2-TL was measured but was also statistically insignificant.

Table 11.25 RAMAL ANGLE (SNArGo) (T1-T2) and relapse pattern (T2-TL) for inverted 'L' , B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups. (measurements in degrees)

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2	0.1	-2.5	0.4
t-value	0.17	-3.47**	0.86
Min.	-3.5	-6.8	-0.4
Max.	6.7	2.9	1.5
Patients	**14**	**15**	**4**
T2-TL	-4.3	0.3	4.4
t-value	-5.23**	0.55	0.98
Min.	-11.3	-3.9	-4.2
Max.	0.8	3.3	13.6

* =p< 0.05

** =p< 0.005

11.3.4 Submandibular changes

11.3.4.1 Hyoid bone horizontal

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.26)

A statistically significant ($p < 0.05$) increase of 3.0 mm was measured with surgery, range -4.1 to 9.2 mm. A further increase of 0.9 mm, range -6.2 to 13.2 mm from T2-TL was measured but was not statistically significant. A positive value implies that the hyoid bone moved anteriorly.

Group II Bilateral sagittal split osteotomy (n=15 Table 11.26)

A statistically significant ($p < 0.05$) increase of 2.8 mm was measured with surgery, range -4.2 to 9.1 mm. An subsequent decrease of (-) 0.3 mm, range -5.1 to 6.9 mm from T2-TL was measured but was not statistically significant.

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.26)

A statistically significant ($p < 0.05$) increase of 7.6 mm was measured with surgery, range 5.2 to 10.1 mm. A subsequent decrease of (-)3.4, range -5.8 to 0.9 mm from T2-TL was measured and was statistically significant ($p < 0.05$).

Table 11.26 Hyx (T1-T2) and relapse pattern (T2-TL) for inverted 'L' , B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (mm)	3.0	2.8	7.6
t-value	2.89*	2.78*	5.70*
Min. (mm)	-4.1	-4.2	5.2
Max. (mm)	9.2	9.1	10.1
Patients	**14**	**15**	**4**
T2-TL (mm)	0.9	-0.3	-3.4
t-value	0.68	-0.39	-3.15*
Min. (mm)	-6.2	-5.1	-5.8
Max. (mm)	13.2	6.9	0.9

* =p< 0.05

** =p< 0.005

11.3.4.2 Hyoid bone vertical

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.27)

A statistically insignificant increase of (-)0.3 mm was measured with surgery, range -7.0 to 5.5 mm. A subsequent decrease of 0.9 mm, range -6.2 to 13.16 mm from T2-TL was measured but again was not statistically significant. A negative value implies an inferior movement.

Group II Bilateral sagittal split osteotomy (n=15 Table 11.27)

A statistically insignificant increase of (-) 0.9 mm was measured with surgery, range -4.7 to 3.5 mm. An further increase of (-) 0.3 mm, range -5.0 to 6.9 mm from T2-TL was measured but was not statistically significant.

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.27)

A statistically insignificant decrease of 0.5 mm was measured with surgery, range -5.7 to 6.2 mm. A subsequent increase of (-)3.4, range -5.1 to -0.9 mm from T2-TL was measured and was statistically significant ($p< 0.05$) .

Table 11.27 Hyy (T1-T2) and relapse pattern (T2-TL) for inverted 'L' , B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (mm)	-0.3	-0.9	0.5
t-value	-0.35	-1.2	0.22
Min. (mm)	-7.0	-4.7	-5.7
Max. (mm)	5.5	3.52	6.2
Patients	**14**	**15**	**4**
T2-TL (mm)	0.9	-0.3	-3.4
t-value	0.68	-0.39	-3.1*
Min. (mm)	-6.2	-5.0	-5.1
Max. (mm)	13.16	6.9	-0.9

* =p< 0.05

** =p< 0.005

11.3.4.3 Pharyngeal depth horizontal (PDH)

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.28)

A statistically significant ($p < 0.05$) increase of 2.1 mm was measured with surgery, range -1.6 to 13.1 mm. A subsequent decrease of (-) 0.4 mm, range -6.3 to 5.0 mm from T2-TL was measured but was not statistically significant.

Group II Bilateral sagittal split osteotomy (n=15 : Table 11.28)

A statistically significant increase of 1.4 mm was measured with surgery, range -1.7 to 4.7 mm. An subsequent decrease of (-) 0.5 mm, range -3.3 to 3.4 mm from T2-TL was measured and was not statistically significant.

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 : Table 11.28)

A statistically insignificant increase of 2.0 mm was measured with surgery, range -1.8 to 5.9 mm. A subsequent decrease of (-)1.0, range -3.4 to 1.2 mm from T2-TL was measured but was not statistically significant.

Table 11.28 PDH (T1-T2) and relapse pattern (T2-TL) for inverted 'L', B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (mm)	2.1	1.4	2.0
t-value	2.03*	2.72*	1.21
Min. (mm)	-1.6	-1.7	-1.8
Max. (mm)	13.1	4.7	5.87
Patients	**14**	**15**	**4**
T2-TL (mm)	-0.4	-0.5	-1.0
t-value	-0.43	0.97	-1.09
Min. (mm)	-6.3	-3.3	-3.4
Max. (mm)	5.0	3.4	1.2

* =p< 0.05

** =p< 0.005

11.3.4.4 Pharyngeal depth vertical (PD y)

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.29)

A statistically significant increase of (-)1.1 mm was measured with surgery, range -5.0 to 1.9 mm. A subsequent increase of 0.4 mm, range -2.1 to 3.3 mm from T2-TL was measured but was not statistically significant.

Group II Bilateral sagittal split osteotomy (n=15 Table 11.29)

A statistically significant increase of (-)1.5 mm was measured with surgery, range -5.4 to 1.0 mm. An subsequent decrease of 1.0 mm, range -1.6 to 3.8 mm from T2-TL was measured and was also statistically significant.

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.29)

A statistically insignificant increase of (-)0.5 mm was measured with surgery, range -4.4 to 2.7 mm. A subsequent decrease of 1.1, range -0.8 to 3.4 mm from T2-TL was measured but was again not statistically significant.

Table 11.29 PD y (T1-T2) and relapse pattern (T2-TL) for inverted 'L', B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (mm)	-1.1	-1.5	-0.5
t-value	-2.42*	-3.48**	-0.27
Min. (mm)	-5.0	-5.4	-4.4
Max. (mm)	1.9	1.0	2.7
Patients	**14**	**15**	**4**
T2-TL (mm)	0.4	1.0	1.1
t-value	0.95	2.82*	1.14
Min. (mm)	-2.1	-1.6	-0.8
Max. (mm)	3.3	3.8	3.4

* =p< 0.05

** =p< 0.005

11.3.5 Dentoskeletal changes

11.3.5.1 Lower incisor to mandibular plane

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.30)

A statistically insignificant decrease of 0.2° was measured with surgery, range -2.6° to 3.7°. A further decrease of -0.1°, range -2.7° to 1.9° from T2-TL was measured and was statistically not significant.

Group II Bilateral sagittal split osteotomy (n=15 Table 11.30)

A statistically significant ($p < 0.05$) decrease of 0.6° was measured with surgery, range -2.4° to 0.6°. An increase of (-)0.1°, range -1.5° to 1.9° from T2-TL was measured and was statistically not significant.

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.30)

A statistically insignificant decrease of 1.1° was measured with surgery, range -4.0° to 1.4°. A further decrease of (-)0.4°, range -1.8° to 1.3° from T2-TL was measured but again was not statistically significant.

Table 11.30 Lower incisor to mandibular plane angle (T1-T2) and relapse pattern (measurements in degrees) (T2-TL) for inverted 'L', B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (°)	-0.2	-0.6	-1.1
t-value	-0.8	-2.78*	-0.77
Min. (°)	-2.6	2.44	-4
Max. (°)	3.7	0.6	1.4
Patients	**14**	**15**	**4**
T2-TL (°)	-0.1	0.1	-0.4
t-value	-0.44	0.13	-0.55
Min. (°)	-2.7	-1.5	-1.8
Max. (°)	1.9	1.9	1.3

* =p< 0.05

** =p< 0.005

11.3.5.2 Interincisal angle

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.31)

A statistically significant ($p< 0.005$) decrease of 4.0° was measured with surgery, range -12.6° to 3.2°. A subsequent increase of 5°, range -5.5° to 15.1° from T2-TL was measured and was statistically significant ($p< 0.005$).

Group II Bilateral sagittal split osteotomy (n=15 Table 11.31)

A statistically insignificant decrease of 1.0° was measured with surgery, range -7.7° to 6.5°. An increase of 3.1°, range -5.6° to 9.7° from T2-TL was measured and was statistically significant ($p< 0.05$).

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.31)

A statistically insignificant increase of 1.2° was measured with surgery, range -2.8° to 6.5°. A decrease of (-)2.8°, range -6.6° to 1.5° from T2-TL was measured but again was not statistically significant.

Table 11.31 Interincisal angle (T1-T2) and relapse pattern (T2-TL) for inverted 'L' , B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (mm)	-4	-1.0	1.2
t-value	-3.78**	-0.86	-0.32
Min. (mm)	-12.6	-7.7	-2.8
Max. (mm)	3.2	6.5	6.5
Patients	**14**	**15**	**4**
T2-TL (mm)	5.0	3.1	-2.8
t-value	3.11**	2.64*	-1.32
Min. (mm)	-5.5	-5.6	-6.6
Max. (mm)	15.1	9.7	1.5

* =p< 0.05

** =p< 0.005

11.3.5.3 Overjet (parallel to SN-7)

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.32)

A statistically significant (p< 0.005) decrease of (-) 5.8 mm was measured with surgery, range -8.0 to -3.9 mm. A subsequent increase of 1.2 mm, range -0.6 to 3.4 mm from T2-TL was measured and was also statistically significant (p< 0.005).

Group II Bilateral sagittal split osteotomy (n=15 Table 11.32)

A statistically significant (p< 0.005) decrease of (-)4.7 mm was measured with surgery, range -2.0 to 4.0 mm. A subsequent increase of 0.8 mm, range -2.0 to 4.0 mm from T2-TL was measured and was statistically significant (p< 0.05) .

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.32)

A statistically significant (p< 0.05) decrease of (-)5.3 mm was measured with surgery, range -8.7 to -2.7 mm. A subsequent increase of 0.9, range -0.3 to 1.45 mm from T2-TL was measured but again was not statistically significant.

Table 11.32 Horizontal overjet (T1-T2) and relapse pattern (T2-TL) for inverted 'L' , B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (mm)	-5.8	-4.7	-5.3
t-value	-15.07**	-9.38**	-4.07*
Min. (mm)	-8.0	-2.0	-8.7
Max. (mm)	-3.9	4.0	-2.7
Patients	**14**	**15**	**4**
T2-TL (mm)	1.2	0.8	0.9
t-value	3.18**	2.06*	2.27
Min. (mm)	-0.6	-2.0	-0.3
Max. (mm)	3.4	4.0	1.4

* =p< 0.05

** =p< 0.005

11.3.5.4 Vertical overbite

Group I Intraoral Inverted 'L'osteotomy (n=14; Table 11.33)

A statistically significant ($p < 0.005$) decrease of (-) 3.7 mm was measured with surgery, range -7.6 to -1.3 mm. A subsequent increase of 1.9 mm, range 0.3 to 4.8 mm from T2-TL was measured and was also statistically significant ($p < 0.005$).

Group II Bilateral sagittal split osteotomy (n=15 Table 11.33)

A statistically significant ($p < 0.005$) decrease of (-)2.8 mm was measured with surgery, range -6.2 to 0.9 mm. A subsequent increase of 1.2 mm, range -2.0 to 4.5 mm from T2-TL was measured and was again statistically significant ($p < 0.05$) .

Group III Extraoral inverted 'L' / LeFort I osteotomy (n=4 Table 11.33)

A statistically insignificant decrease of (-)0.3 mm was measured with surgery, range -2.2 to 2.1 mm. There was no mean change , range -0.3 to 0.5 mm from T2-TL but again was not statistically significant.

Table 11.33 Vertical overbite (T1-T2) and relapse pattern (T2-TL) for inverted 'L' , B.S.S.O. and extraoral inv 'L' + Le Fort 1 groups.

GROUP	INV. L	BSSO	EO INVL +LF1
Patients	**14**	**15**	**4**
T1-T2 (mm)	-3.7	-2.8	-0.3
t-value	-7.69**	-5.21**	-0.29
Min. (mm)	-7.6	-6.2	-2.2
Max. (mm)	-1.3	0.9	2.1
Patients	**14**	**15**	**4**
T2-TL (mm)	1.9	1.2	0.0
t-value	5.54**	2.92*	0.20
Min. (mm)	0.3	-2	-0.3
Max. (mm)	4.8	4.5	0.5

* =p< 0.05

** =p< 0.005

11.3.6 Correlation results

The correlation between horizontal relapse at point B and selected variables was assessed.

11.3.6.1 Sex of patient (Table 11.34)

Table 11.34 Comparison of relapse at point B(x) T2-TL and sex.

Group	t- Value	Probability
Group I males v females	-1.02	0.32
Group II males v females	0.97	0.35

11.3.6.2 Age of patient at time of surgery and horizontal relapse at point B

When all subjects were included there was a low inverse correlation between age and movement at point B (r squared =8.61) correlation -0.009. (Figure 11.2)

Group I showed a low positive correlation 0.339 (r squared =0.115), whereas Group II showed a low inverse correlation - 0.322 (r squared =0.104). Group III showed a low negative correlation -0.288 (r squared =0.083). (Figures 11.3-5)

Figure 11.2 Correlation between age at time of surgery and horizontal relapse at point B (mm) T2-TL for all groups.

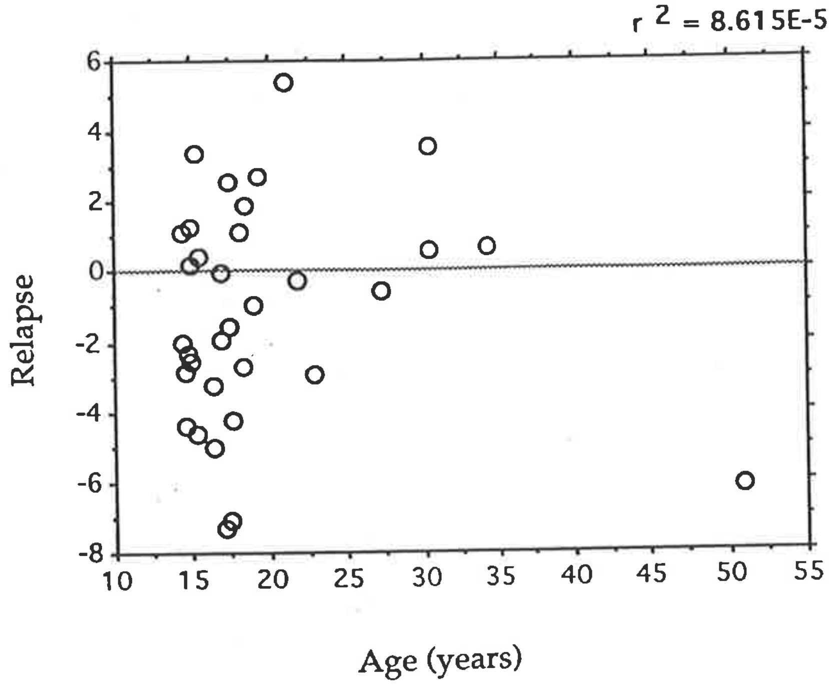


Figure 11.3 Correlation between age at time of surgery and horizontal relapse at point B (mm) T2-TL for Group I.

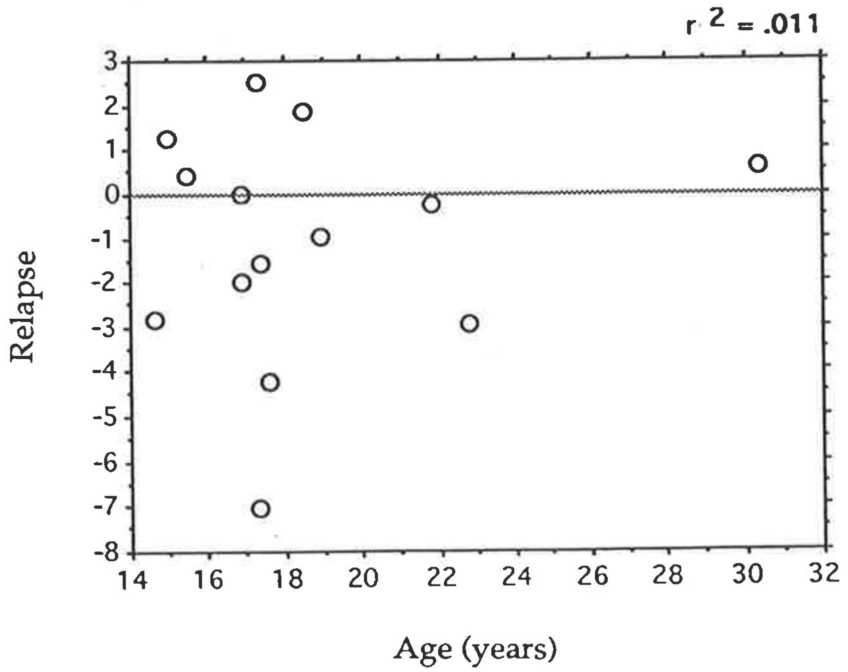


Figure 11.4 Correlation between age at time of surgery and horizontal relapse at point B (mm) T2-TL for Group II.

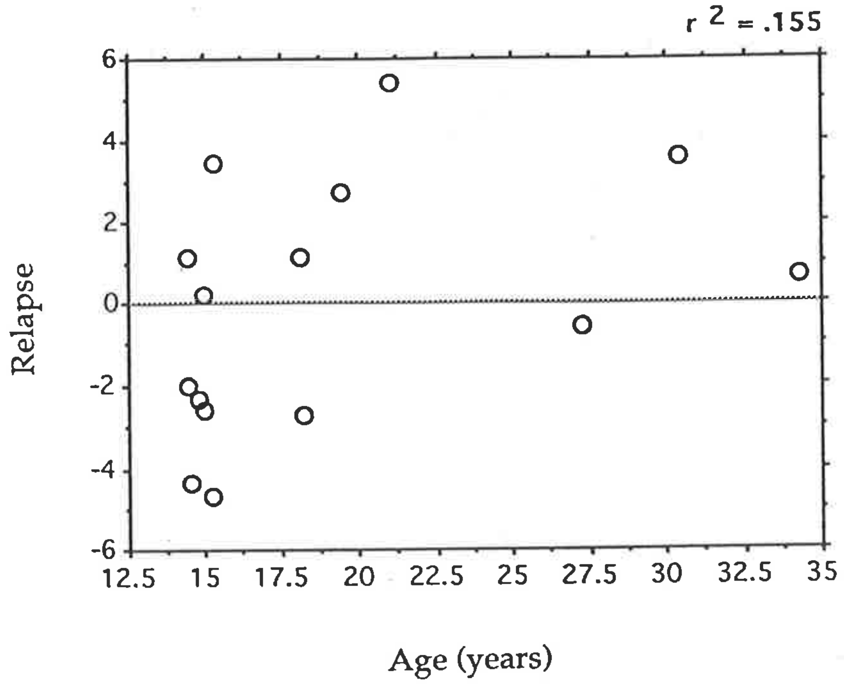
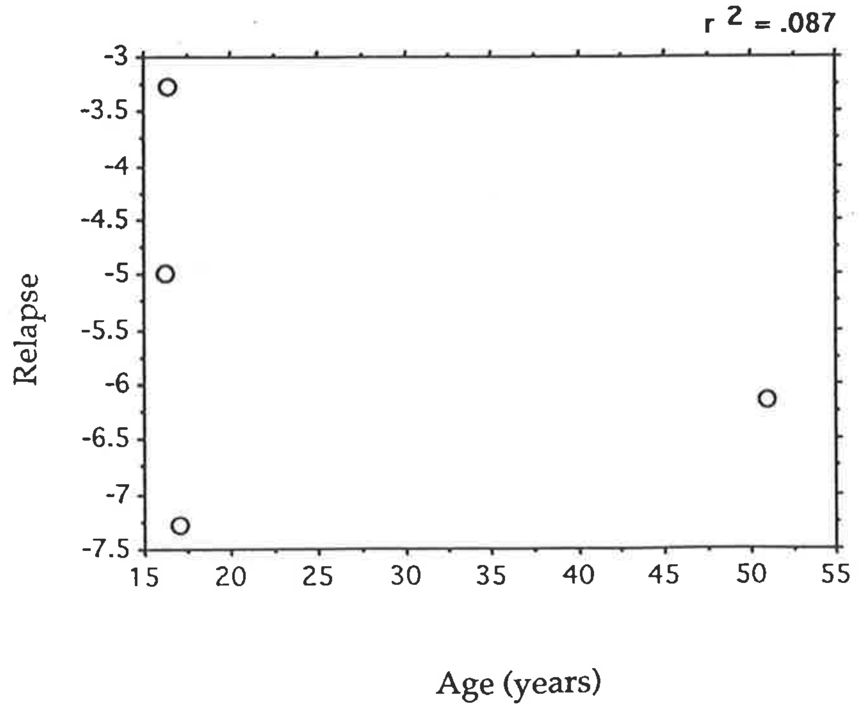


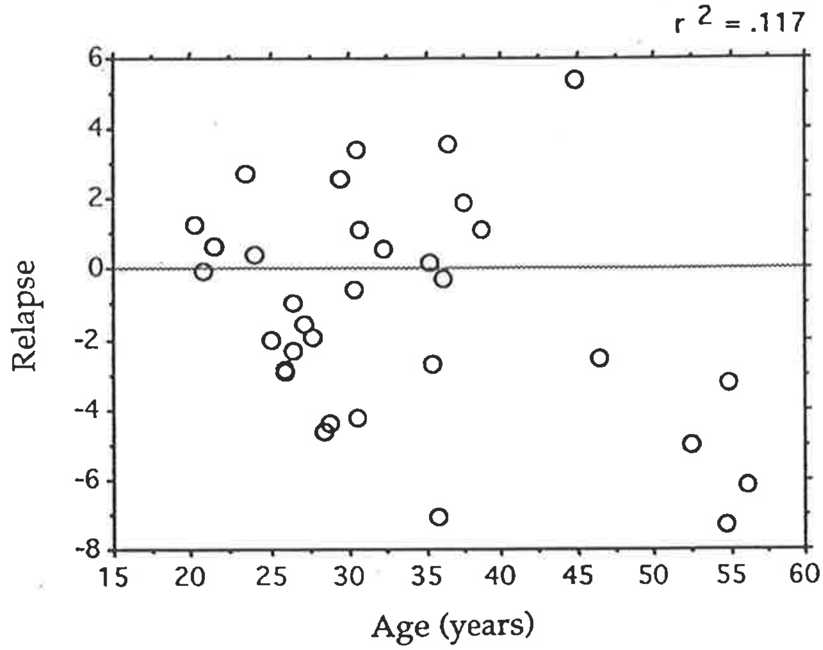
Figure 11.5 Correlation between age at time of surgery and horizontal relapse at point B (mm) T2-TL for Group III.



11.3.6.3 Preoperative SNGoMe and horizontal relapse at point B

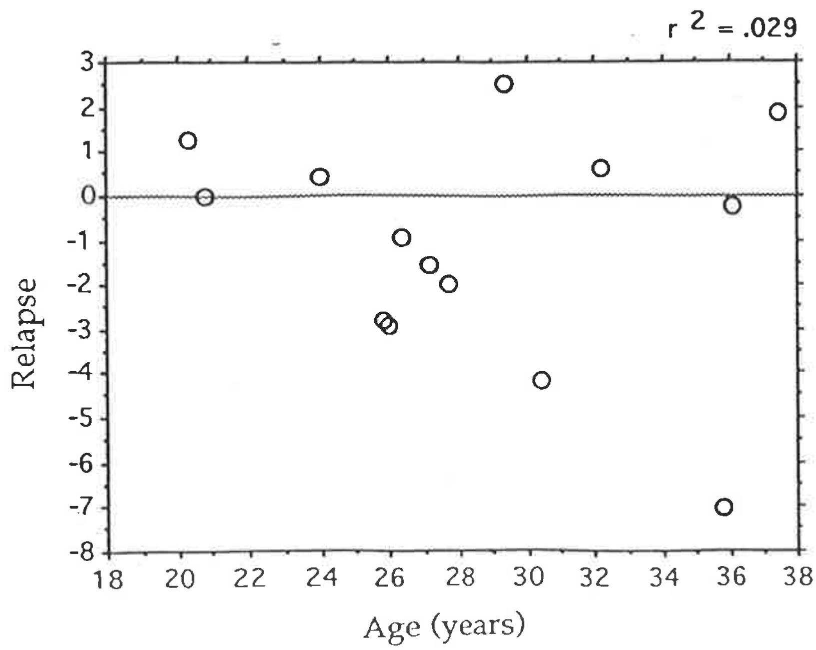
When all subjects were included there was a low inverse correlation between the preoperative SNGoMe angle and relapse at point B (r squared =0.117), correlation-0.342. (Figure 11.6)

Figure 11.6 Correlation between preoperative mandibular plane angle and horizontal relapse at point B for all subjects.



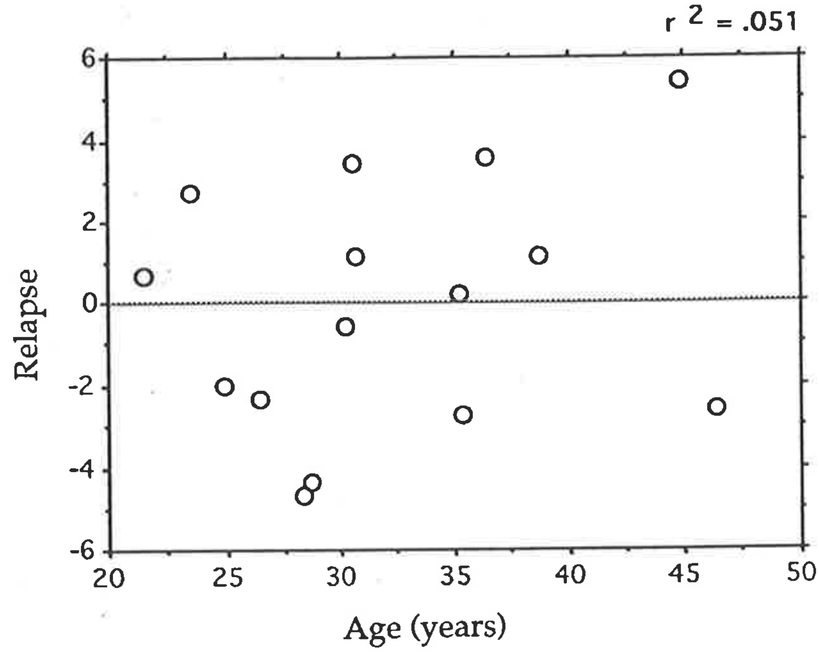
With Group I there was a low inverse correlation between the preoperative SNGoMe angle and relapse at point B (r squared =0.029), correlation -0.171. (Figure 11.7)

Figure 11.7 Correlation between preoperative mandibular plane angle and horizontal relapse at point B for Group I.



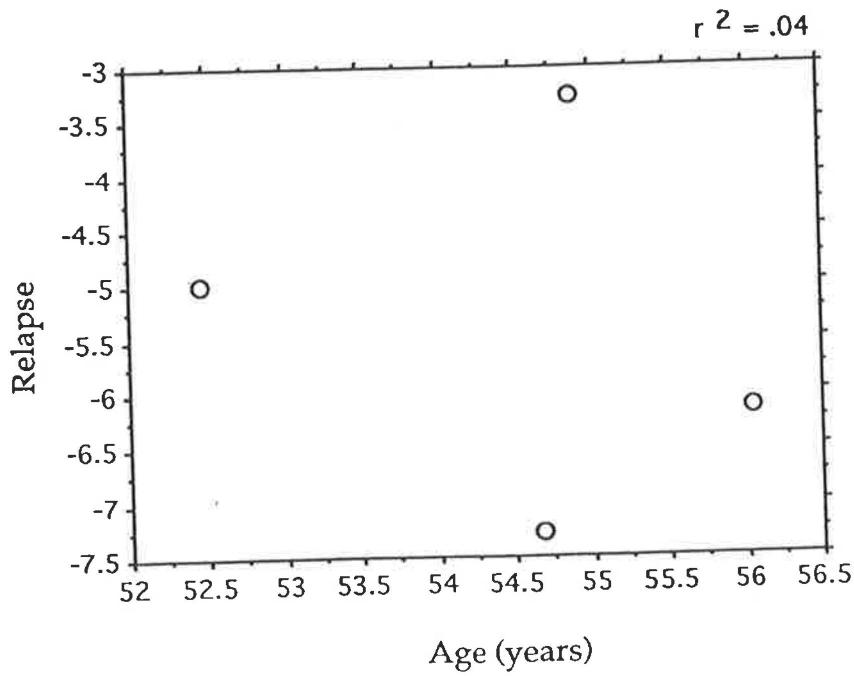
With Group II there was a low positive correlation between the preoperative SNGoMe angle and relapse at point B (r squared =0.051), correlation-0.227. (Figure 11.8)

Figure 11.8 Correlation between preoperative mandibular plane angle and horizontal relapse at point B for Group II.



With Group III there was a low inverse correlation between the preoperative SNGoMe angle and relapse at point B (r squared =0.04), correlation-0.2. (Figure 11.9)

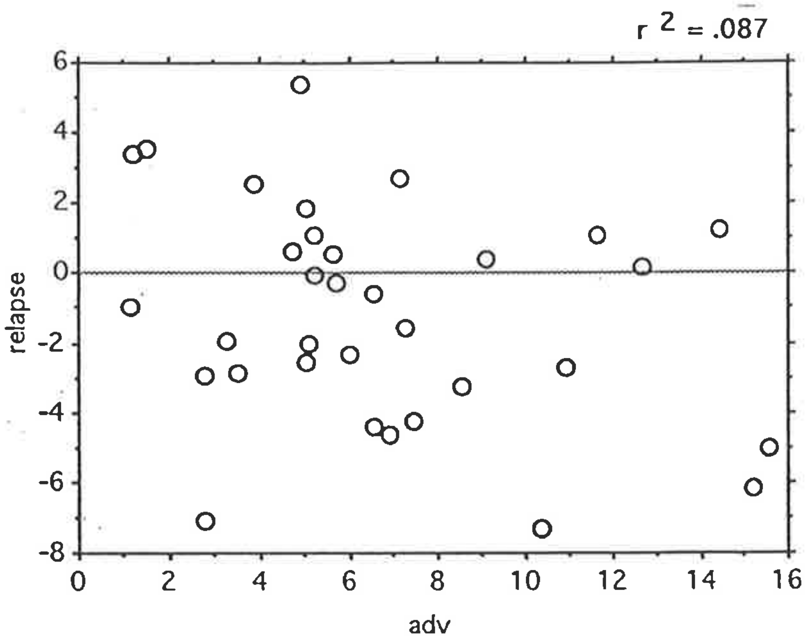
Figure 11.9 Correlation between preoperative mandibular plane angle and horizontal relapse at point B for Group III.



11.3.6.4 Surgical advancement and horizontal relapse at point B

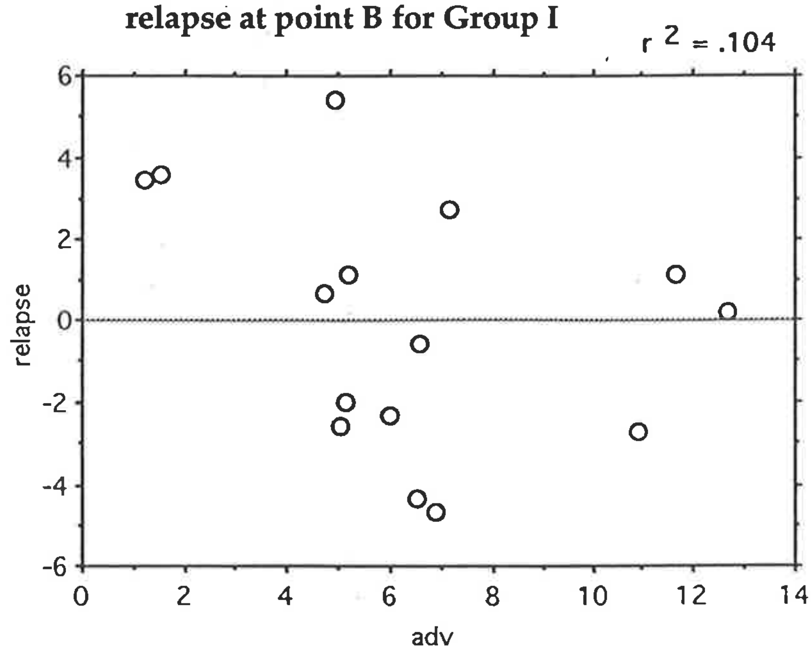
When all subjects were included there was a low inverse correlation between the preoperative advancement and relapse at point B (T2-TL)(r squared =0.087), correlation-0.295. (Figure 11.10)

Figure 11.10 Correlation between surgical advancement and horizontal relapse at point B for all subjects.



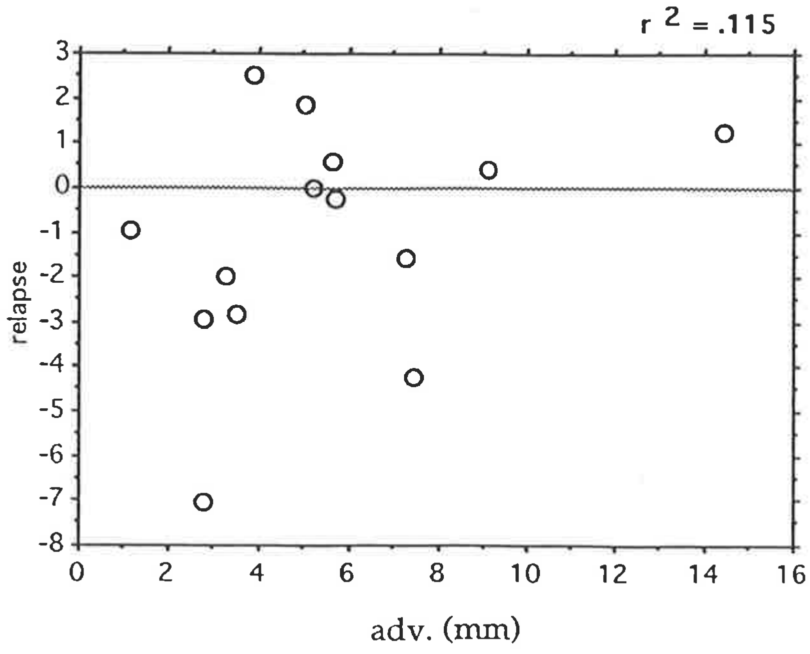
With Group I there was a low positive correlation between surgical advancement and relapse at point B (T2-TL) (r squared =0.115), correlation 0.339. (Figure 11.11)

Figure 11.11 Correlation between surgical advancement and horizontal relapse at point B for Group I



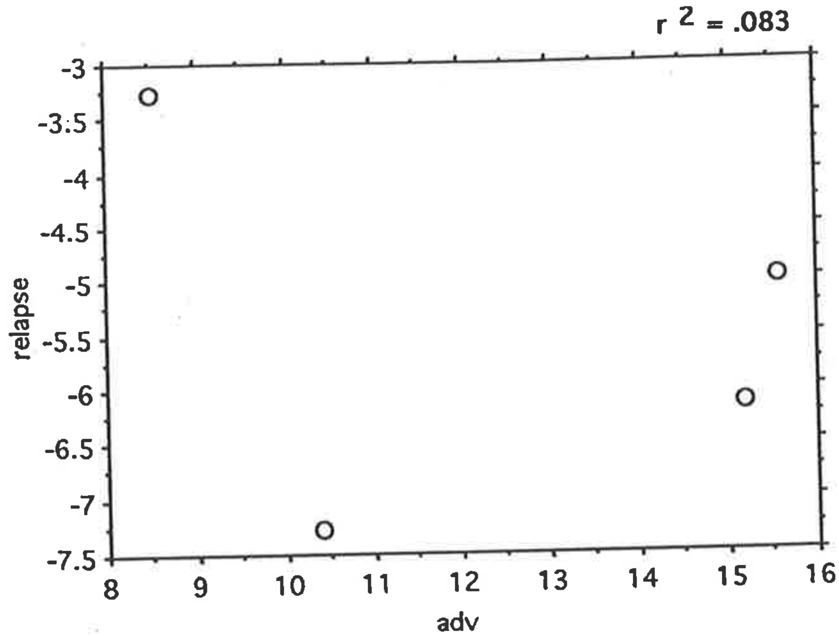
With Group II there was a low inverse correlation between surgical advancement and relapse at point B (r squared =0.104), correlation -0.322. (Figure 11.12)

Figure 11.12 Correlation between surgical advancement and horizontal relapse at point B for Group II



With Group III there was a low inverse correlation between surgical advancement and relapse at point B (r squared =0.083), correlation 0.288. (Figure 11.13)

Figure 11.13 Correlation between surgical advancement and horizontal relapse at point B for Group III



CHAPTER 12

RESULTS ERROR OF THE METHOD

12.1 ERRORS OF THE METHOD

The magnitude of errors in the horizontal and vertical axes for ten sets of double determinations were calculated and summarised in Tables 12.1 and 12.2. The maximum mean difference measured in either the horizontal or vertical was 1.1 mm. The mean differences in the vertical dimension had more error when compared to the mean differences in the horizontal dimension. The errors for the mean differences ranged from 0.17 to 0.60 for the horizontal and 0.14 to 0.85 for the vertical. The standard errors for the mean differences varied widely and ranged from 0.36 to 1.31 for the horizontal axis and from 0.31 to 1.52 for the vertical axis.

The most variable point in identification in the horizontal plane was the point AI (lower incisor apex) with the standard error of the mean being measured at 1.31 mm. The spread of values for this point in the horizontal plane ranged from -2.9 to 3.0 mm. In the vertical plane the most variable point was point B with a standard error of the mean being 1.52 mm. The spread of values for this point ranged from -3.2 to 4.2 mm in the vertical plane.

The most reliable point in the horizontal plane was Sella with a standard error value of 0.36 mm. In the vertical plane the most reliable point was Hyoid with a standard error of 0.31 mm.

Table 12.1 Error for variables (horizontal axis) by double determination

Variable	M diff	E(M diff)	Min	Max	S(error)
S x	0.0	0.17	-1.1	0.6	0.36
N x	-0.4	0.18	-0.8	0.8	0.38
Co x	-0.5	0.37	-2.1	1.3	0.87
HA x	0.1	0.27	-0.9	1.3	0.59
Ar x	0.1	0.26	-1.1	1.6	0.55
Go x	0.4	0.39	-2.0	2.3	0.88
Me x	0.4	0.50	-2.1	2.3	1.08
B x	0.5	0.46	-1.1	2.9	1.04
AI x	0.4	0.60	-2.9	3.0	1.31
II x	0.3	0.29	-0.8	1.5	0.64
IS x	0.4	0.38	-1.3	2.2	0.85
AS x	0.3	0.46	-1.5	3.8	1.00
MI x	0.1	0.40	-1.4	2.1	0.85
CV x	0.5	0.34	-1.8	1.6	0.81
PPW x	0.6	0.41	-1.5	2.1	0.97
APW x	0.3	0.37	-1.6	1.9	0.80
HY x	0.5	0.52	-1.8	2.5	1.15

Table 12.2 Error for variables (vertical axis) by double determination

Variable	M diff	E(M diff)	Min	Max	S(error)
S y	-1.1	0.25	-1.0	1.2	0.54
N y	-0.6	0.39	-1.4	2.5	0.92
Co y	0.9	0.40	-0.5	3.4	1.06
HA y	0.1	0.33	-1.2	1.5	0.70
Ar y	-0.8	0.21	-1.8	0.2	0.71
Go y	-0.8	0.33	-1.8	0.7	0.88
Me y	0.5	0.41	-0.9	2.6	0.95
B y	-0.1	0.72	-3.2	4.3	1.52
AI y	-0.1	0.65	-3.6	3.6	1.43
II y	0.7	0.40	-1.2	2.6	0.98
IS y	0.4	0.37	-1.3	2.0	0.83
AS y	0.5	0.56	-3.0	2.5	1.24
MI y	-0.0	0.85	-1.0	1.1	0.57
CV y	0.1	0.15	-0.6	0.7	0.32
PPW y	-0.0	0.24	-1.0	1.4	0.51
APW y	0.3	0.18	-0.5	1.2	0.44
HY y	0.1	0.14	-0.7	0.5	0.31

The Students t-test for paired values revealed no points were statistically significant in the horizontal plane, however in the vertical plane Sella and Articulare were both significant at the 5% level.

Scattergrams for each of the hard and soft tissue points are illustrated showing errors in the horizontal and vertical axes. (Figures 12.1 - 12.16)

Figure 12.1 Differences between digitised double determinations for nasion (N)

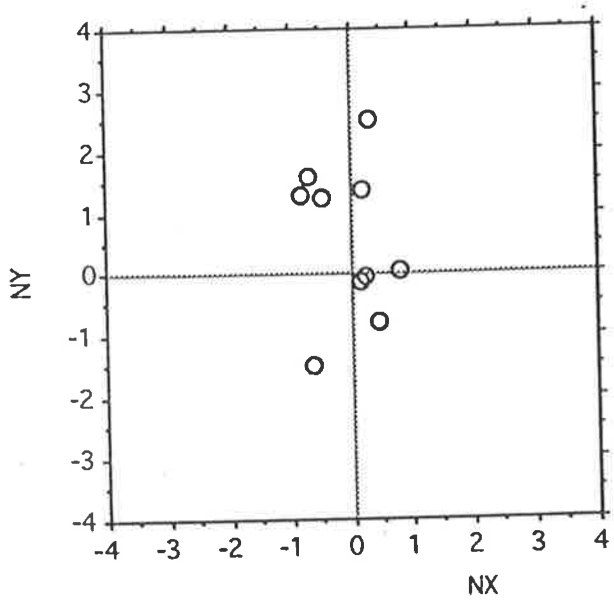


Figure 12.2 Differences between digitised double determinations for Sella (S)

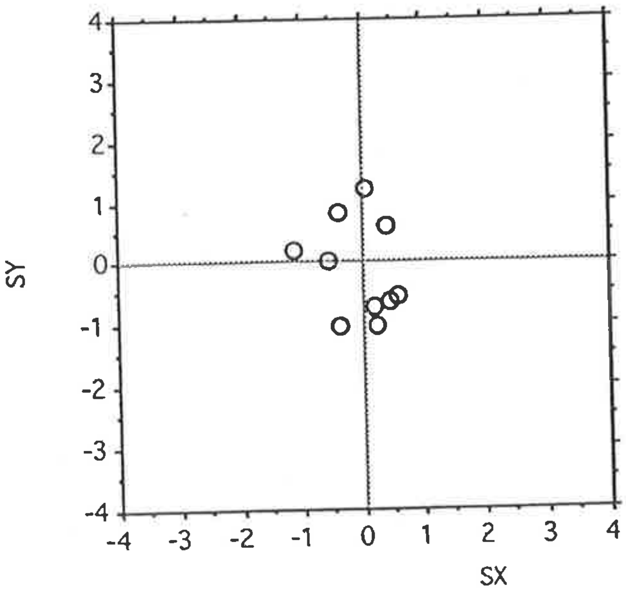


Figure 12.3 **Differences between digitised double determinations for Condylion (Co)**

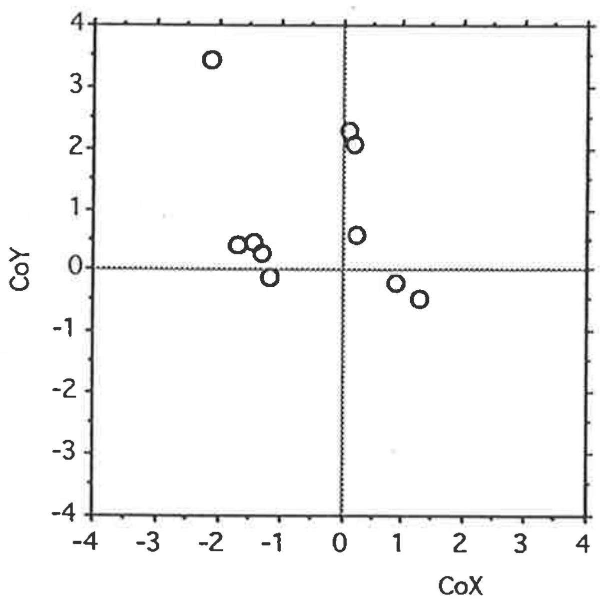


Figure 12.4 **Differences between digitised double determinations for Hinge axis (HA)**

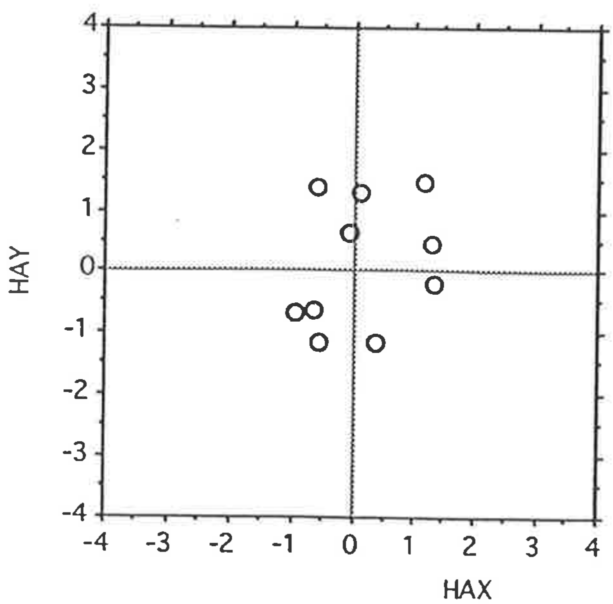


Figure 12.5 Differences between digitised double determinations for Articulare (Ar)

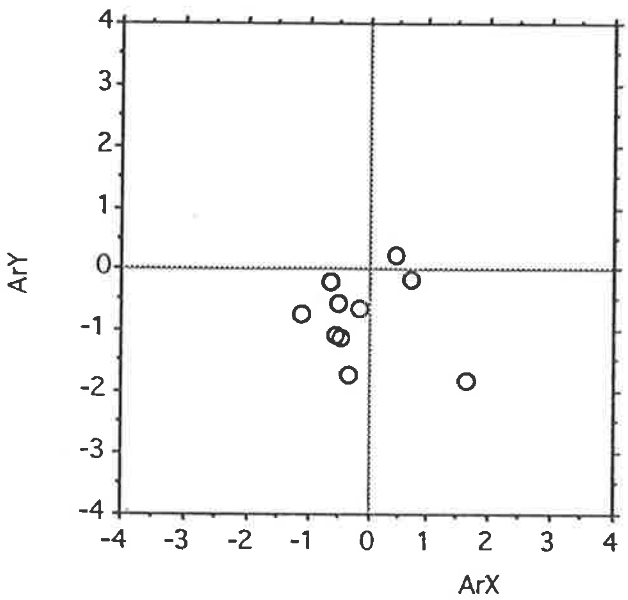


Figure 12.6 Differences between digitised double determinations for Gonion (Go)

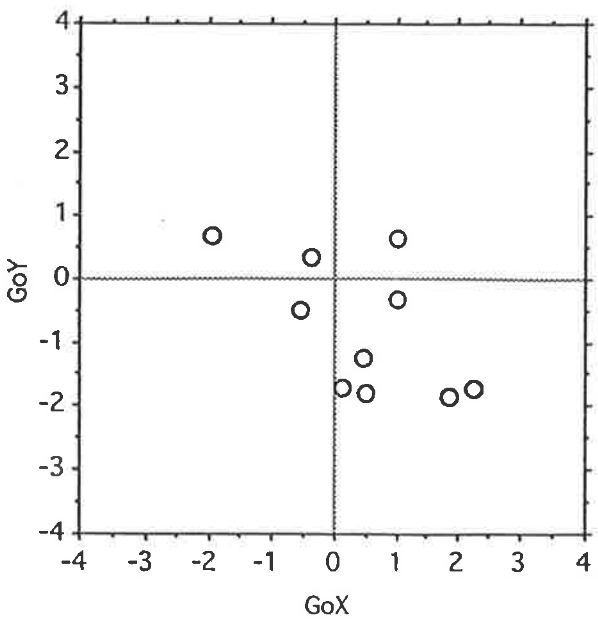


Figure 12.7 Differences between digitised double determinations for Menton (Me)

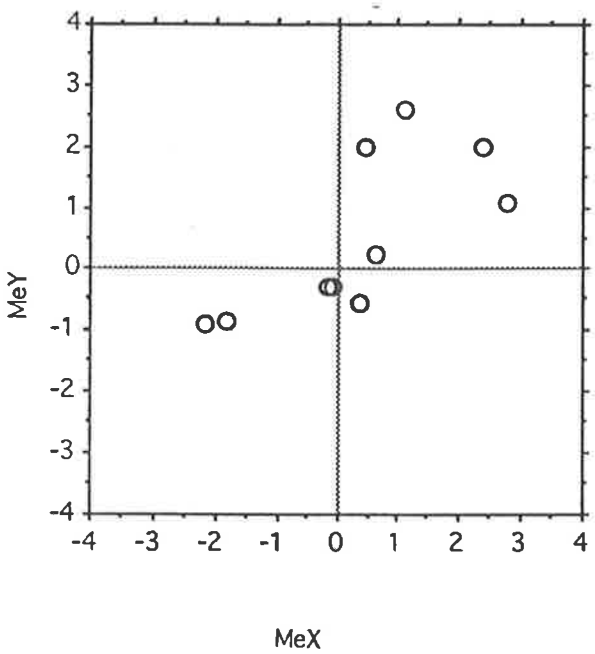


Figure 12.8 Differences between digitised double determinations for Point B (B)

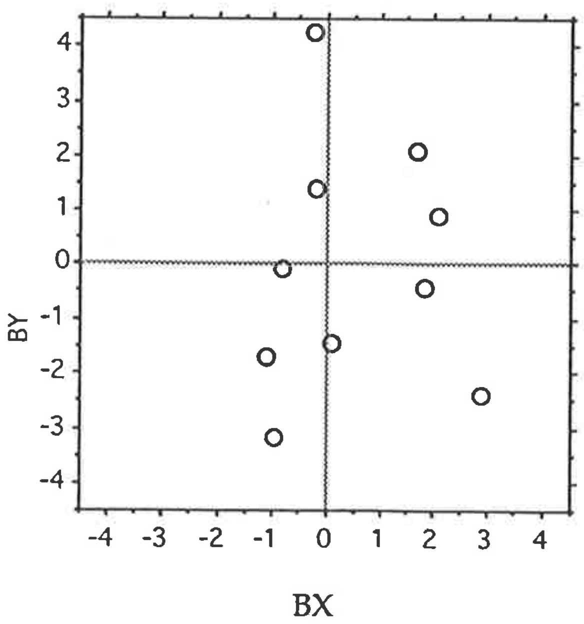


Figure 12.9 Differences between digitised double determinations for Lower incisor apex (AI)

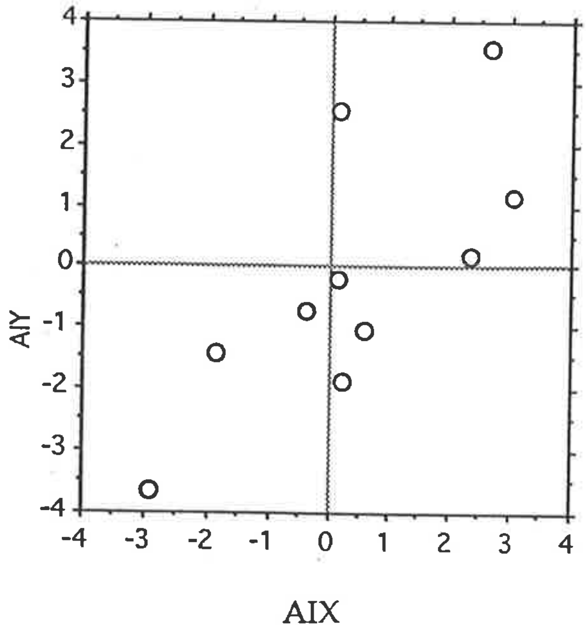


Figure 12.10 Differences between digitised double determinations for Lower incisor edge (II)

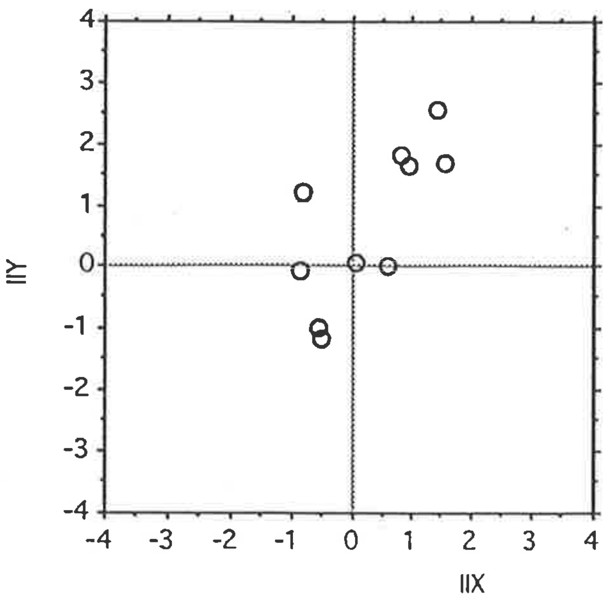


Figure 12.11 Differences between digitised double determinations for Upper incisor edge (IS)

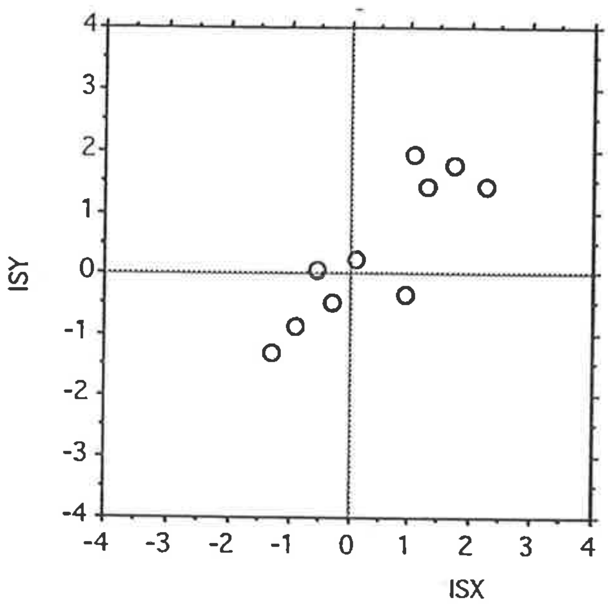


Figure 12.12 Differences between digitised double determinations for Upper incisor apex (AS)

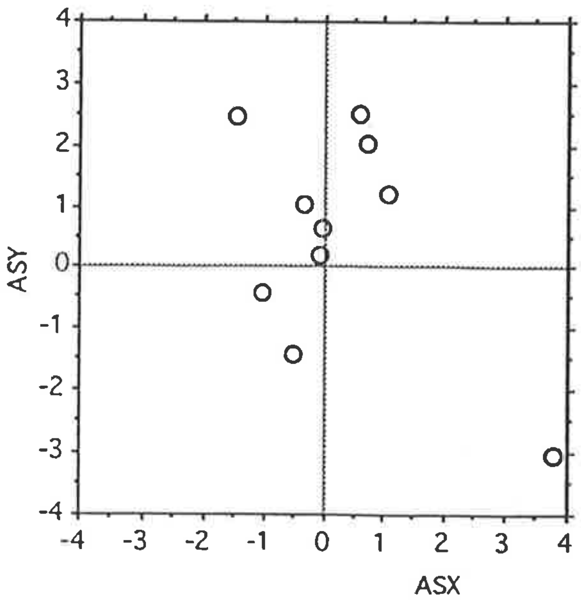


Figure 12.13 Differences between digitised double determinations for Lower molar crown (MI)

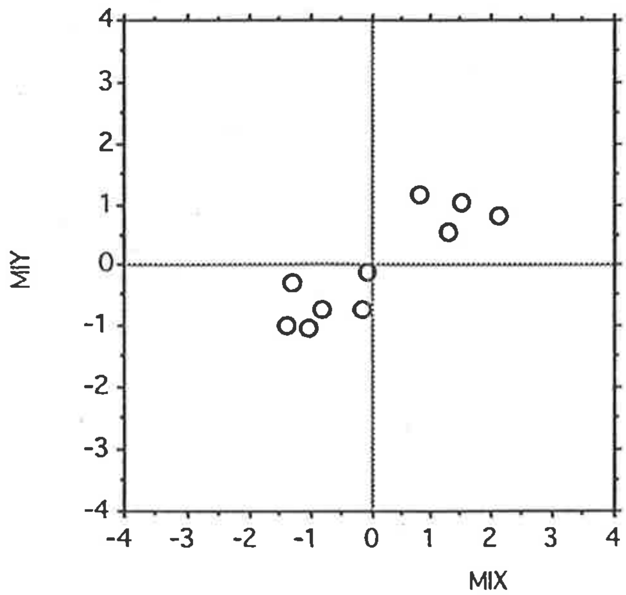


Figure 12.14 Differences between digitised double determinations for Cervical vertebrae 2 (Cv2)

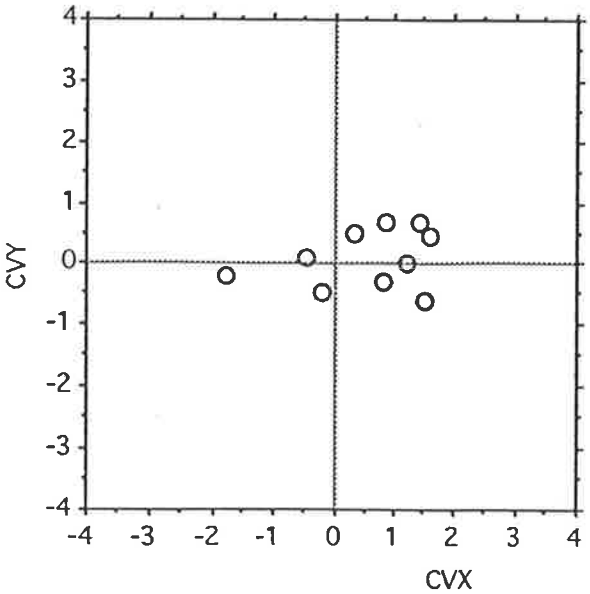


Figure 12.15 Differences between digitised double determinations for Posterior pharyngeal wall (PPw)

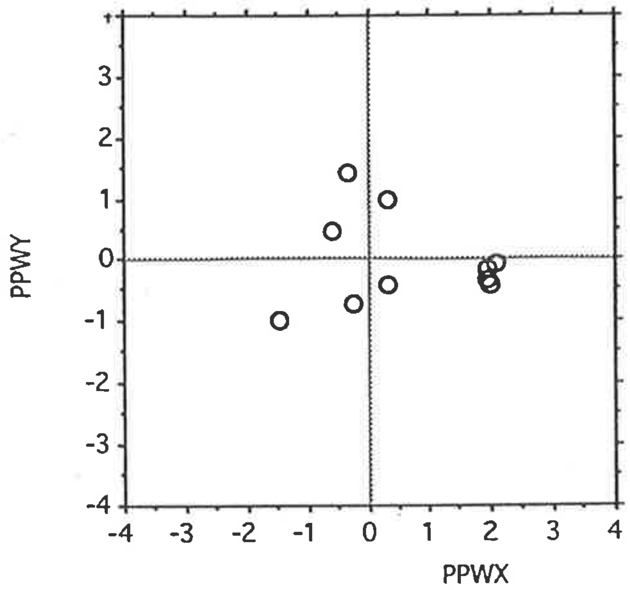


Figure 12.16 Differences between digitised double determinations for Anterior pharyngeal wall (APw)

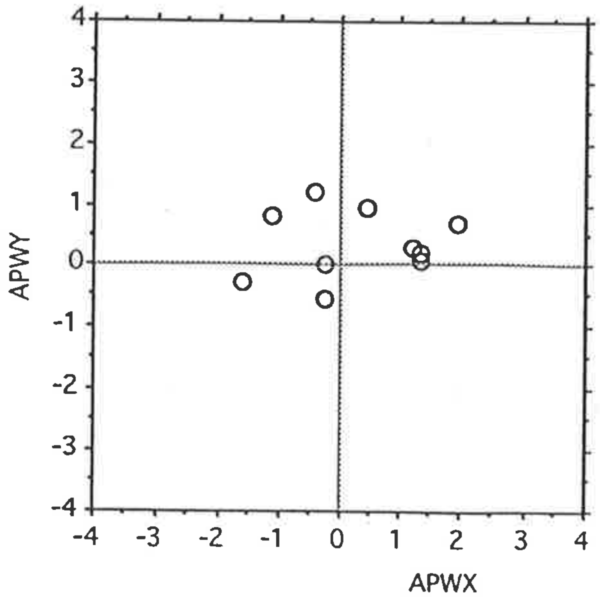
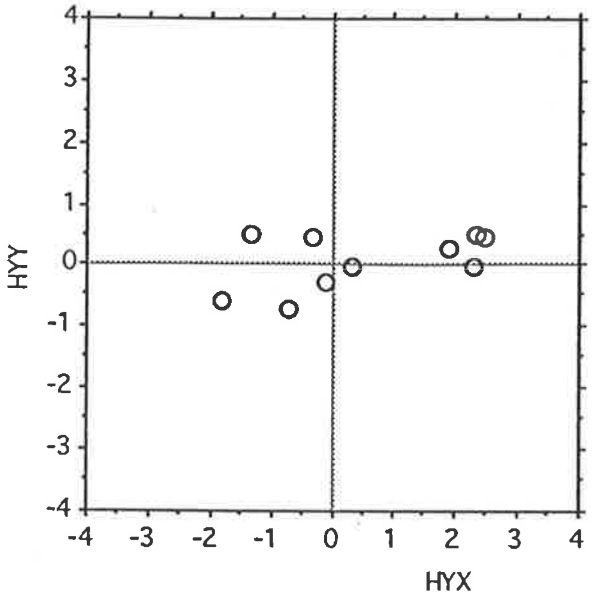


Figure 12.16 Differences between digitised double determinations for Hyoid (HY)



CHAPTER 13

RESULTS OF NEUROSENSORY TESTING

Twenty subjects were tested, the composition by sex is shown in Table 13.1 and by age in Table 13.2

Table 13.1 Composition by sex

Group	Males	Females	Total
Group I (inv 'L')	3	6	9
Group II (BSSO)	4	5	9
Group III (inv 'L' + L.F.I)		2	2

Of the nine patients in Group I, two had genioplasties performed, both were females. In Group II, one male patient had a genioplasty performed. Both of the patients in Group III had genioplasties performed.

Table 13.2 Patients age (years) by Group

Group	Mean age	Std. Dev.	Min.	Max.	Range
Group I (inv. 'L')	19.1	4.8	14.7	30.4	15.7
Group II (B.S.S.O.)	17.9	4.2	14.3	27.3	13.0
Group III (Inv'L'+LF.I)	16.3	0	16.3	16.3	0

Table 13.3 Time elapsed since surgery (months) at time of testing.

Group	Time	Std. Dev.	Min.	Max.	Range
Group I (inv. 'L')	21.8	7.2	10	34	24
Group II (B.S.S.O.)	27.7	16.8	11	50	39
Group III (Inv'L'+LF.I)	12	5.7	8	16	8

Subjective findings

No patients in Groups I or III reported any alteration of sensation at the time of testing compared to the preoperative state. Three patients from Group II reported reduced sensation at the time of testing, in two the reduced sensation was bilateral and in one it was unilateral. None of the three patients who reported a reduction in sensation had had genioplasties performed.

Objective neurosensory testing

All subjects in all groups tested positive for light touch and pinprick.

The results of the two point discrimination are summarised in Table 13.4.

Table 13.4 Two point discrimination

Group	Distance (mm)	Std. Dev.	Min.	Max.	Range
Group I (inv. 'L')	7.0	1.2	5	8	3
Group II (B.S.S.O.)	9.1	3.5	4	20	16
Group III (Inv'L'+LF.I)	7	1.1	6	8	2

Group I and II were significantly different , unpaired t value 2.30, probability 0.028.

The patient who reported reduced sensation unilaterally had a two point discrimination threshold of 20 mm on that side. The two patients who reported reduced sensation bilaterally had thresholds of 12 and 8 mm and 8 and 4 mm respectively.

CHAPTER 14

SUMMARY OF RESULTS

14.1 SUMMARY OF RESULTS

Extensive analysis of the relatively small number of subjects showed considerable heterogeneity. A summary of the results of skeletal changes of the type commonly presented in the literature is presented in Table 14.1.

Table 14.1 Summary of dentoskeletal changes for Groups I, II and III.

		Group I	Group II	Group III
B x (mm)	T1-T2 T2-TL	5.5** -1.1	6.4** -0.1	12.4** -5.4**
B y (mm)	T1-T2 T2-TL	-3.3** 0.4	-2.7 -0.7	1.3 -0.7
SNB (°)	T1-T2 T2-TL	3.2** -0.8**	4.2** -0.6	6.6** -2.8**
SNGoMe (°)	T1-T2 T2-TL	1.9* 2.1*	0.7 0.2	-12.2** 3.5**
AFH (mm)	T1-T2 T2-TL	4.2** -0.3	3.2** 1.4*	1.7 -0.1
PFH (mm)	T1-T2 T2-TL	0.2 -1.3*	0.2 0.7**	1.6 -3.5
ArGoMe (°)	T1-T2 T2-TL	1.7 6.4**	3.2** -0.1	-12.6** -0.9
SNArGo (°)	T1-T2 T2-TL	0.1 -4.3**	-2.5** 0.3	0.4 4.4
H x (mm)	T1-T2 T2-TL	3.0* 0.9	2.8* -0.3	7.6* -3.4*
H y (mm)	T1-T2 T2-TL	-0.3 0.9	-0.9 -0.3	0.5 -3.4*
PDH x (mm)	T1-T2 T2-TL	2.1* -0.4	1.4* -0.5	2.0 -1.0
PDH y (mm)	T1-T2 T2-TL	-1.1* 0.4	-1.5** 1.0*	-0.5 1.1

* =p< 0.05 ** =p< 0.005

V

DISCUSSION

CHAPTER 15

DISCUSSION

15.1 INTRODUCTION

This study shows that there is no statistically significant difference between the Inverted 'L' osteotomy and the bilateral sagittal split osteotomy in terms of relapse of point B. The results of this study showed that there were few statistically significant differences between Group I and II for the extensive list of variables studied. Group III was however statistically significantly different to the other groups in several respects.

The inverted 'L' osteotomy was found to have a lower incidence of neurosensory deficit than the bilateral sagittal split osteotomy.

15.2 PATIENT SELECTION

In the retrospective arm of the relapse study twenty case records were retrieved from the surgical files of either the South Australian Oral and Maxillofacial Surgery Unit or the private practice of R.H.B.J. Of the 20 patients who underwent surgery only 5 were accepted into the study. In the prospective arm of the study thirty nine patients underwent surgery however only 28 patients were included in the study. The remainder of the patients from both arms of the study were excluded because of incomplete radiographic records.

The reasons for incomplete radiographic records were:

(i) Patients failed to attend their review appointments.

(ii) The operator failed to request the appropriate radiograph.

(iii) The radiographs had been taken but could not be located.

The reasons why patients failed to attend is unclear in many cases, however it is known that several of the patients changed address, some moved interstate and could not return for review and others failed to advise of their new address and could not be traced. Some had work or family commitments and could not give up their time to attend for review. As the patient pool was from both private practice and the public system a broad cross section of socio-economic groups would have been representative and varying factors would contribute to failure to attend. An unpublished study by Dr M. Bell of the University of Adelaide Department of Geography which found that Australians move house an average of 11 times during their lives. This is more than double that of people living in Europe. Most Australians have completed half of their moves by age 27. (Hannon 1997) It is not surprising therefore that many patients are lost to follow up.

Of note is the fact that the prospective arm had fewer sets of incomplete records this was due to greater care being taken in requesting and storing the radiographs and in ensuring that the patients attended for review.

It is a common problem with studies of this kind that records are incomplete, Ching (1995) found that fewer than 50% of records from a sample of 53 were complete.

All patients selected had preoperative and postoperative orthodontics although this was not a prerequisite for inclusion in the study.

With the neurosensory arm of the study clinic appointments were mailed to all the public patients (26 patients) whose records were included in the relapse study only 20 of these attended their appointment. The reasons for the patients failure to attend were probably similar to those for failure to attend other appointments. Because a single clinical assistant who was blind to the nature of the surgery that the patients had undergone performed the testing, specific clinics were arranged for these sessions. If the patient missed their appointment they were issues with a further appointment, after three failed appointments no further appointments were sent. It may have been an advantage having the neurosensory testing carried out by a clinician who was available to test the patients during their normal review appointments as the patients would have had fewer appointments to keep and more subjects may have been able to have been tested. However this is difficult to arrange in a busy Oral and Maxillofacial Surgery unit.

In Groups I and II females outnumbered males, and Group III consisted entirely of females. This finding is consistent with most orthognathic studies where females usually predominate eg McDonald et al (1987), Van de Perre et al (1996).

Groups I and II as noted were similar preoperatively in terms of age, sex, and deformity, whereas Group III were very different in terms of pathology and degree of deformity.

15.3 MATERIALS AND METHOD

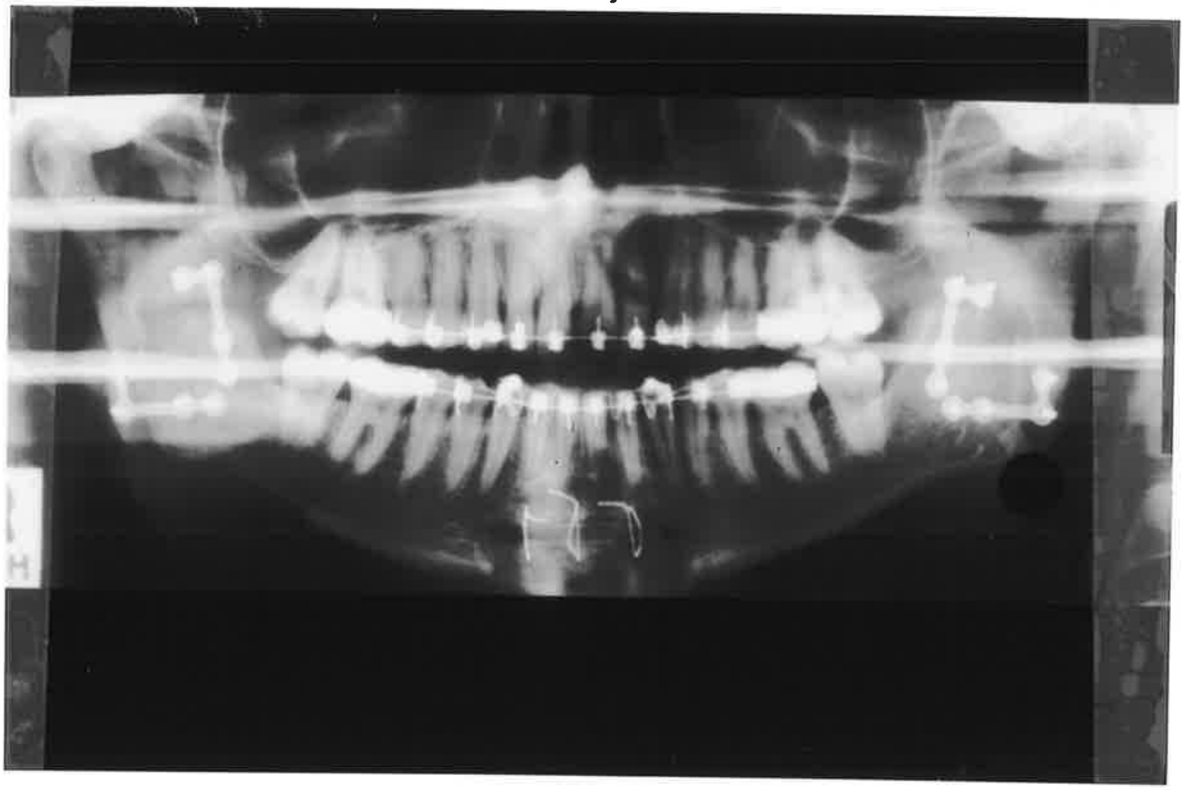
The strengths of this study are that all patients were operated on by the one surgeon (R.H.B.J.) and all radiographs were traced and analysed by the one person (BM).

The weaknesses of the study are the relatively small numbers of cases and the diversity of the groups. Ideally it would be desirable to have patients who were solely having mandibular advancements without genioplasties, however one needs to direct treatment to correcting the patients deformity. Groups I and II therefore contain some patients who had genioplasties. Group III is very different to groups I and II in terms of the degree and type of mandibular deformity and also the fact that there was maxillary deformities requiring maxillary surgery. Group III was included in the study mainly for comparison to Group I.

Two miniplates were placed on each mandibular ramus for fixation following mandibular advancement (Figure 15.1) as several authors including Hammer et al (1995) have suggested that a single miniplate with monocortical screws is probably inadequate for fixation of an osteotomy site if no IMF is used.

The technique of intra oral inverted 'L' osteotomy is not described in any detail in the literature, accordingly R.H.B.J. drew on his experience with other types of osteotomies, modified existing techniques and refined the procedure. (McMillan et al 1997) As with any new technique there is a learning curve and it was found that as time went by the procedure could be completed in less time and with less effort.

Figure 15.1 Panoramic radiograph showing fixation used for intraoral inverted 'L' osteotomy.



15.4 DEFINITION OF RELAPSE

Point B was used primarily in this study to assess relapse because it is relatively easy to identify and because it is not affected by genioplasty as the cuts are placed inferior to it. The relative position of Point B was transferred from the preoperative radiograph onto the post operative tracing using a template. Of note was the fact that the horizontal and vertical movements are inextricably linked, this was highlighted by the case of the female patient from group 2 who appeared to move anteriorly 5.4 mm, this particular patient being in her twenties and would have ceased growth. When the vertical movement was measured it was seen that Point B had simultaneously moved superiorly 5.0 mm. Various authors including Van Sickels and Flanary (1985) and Kierl et al (1990) noted anterior movement of point B in their series and felt that this was most probably due to mandibular rotation secondary to decreasing facial height. Reitzik (1980) uses vector diagrams to show the resultant movement of vertical and horizontal changes, this is a helpful method of expressing the changes.

The mean relapse of point B seen in this study from T2-TL ranges from 1.5% of the original advancement for the bilateral sagittal split group, 20% for the intraoral inverted 'L' group to 43% for the extraoral inverted 'L' group with combined Le Fort I osteotomies.

The findings of relapse of point B in the horizontal plane are consistent with the findings of Farrell and Kent (1977) who found a relapse of 23% of the initial advancement with the 'C' osteotomy which is essentially a minor variant of the inverted 'L' osteotomy.

The relapse of point B found in this study is more than that found by Barer et al (1987) and Reitzik (1981), who found no postoperative relapse with the inverted 'L' osteotomy. When one considers the error of the method, this study is not in disagreement with Barer et al and Reitzik.

The female patient in the intraoral inverted 'L' group who relapsed more than the original advancement is an example of individual variation. The reason for the marked relapse is unclear and on examination of the postoperative radiographs it would appear that the condyles were resorbing. Gassman et al (1990) however report that relapse due to condylar resorption occurs late, early relapse being due to either failure to seat the condyles or movement at the osteotomy site. The patient showed early relapse and as a condylar positioning plate was used it would be unlikely to be due to inadequate condylar seating.
The patient did have a pre existing high mandibular plane angle and was a young female, characteristics which place her at risk of condylar resorption

according to Moore et al (1991). The relapse was noticed to commence within two weeks of surgery and Class 2 elastics were placed in an effort to minimise the relapse. The skeletal relapse continued but the incisors remained close to a Class I relationship due to retroclination of the upper incisors and proclination of the lower incisors. The patient was not unhappy with the end result.

The relapse of point B in the horizontal for Group II supports the findings of many studies in the literature such as Van Sickels et al (1985) and Gassman et al (1990).

15.5 ORTHODONTICS AND OCCLUSION

The use of presurgical and post surgical orthodontics has been reported to influence skeletal stability however in this study as all patients underwent pre and post surgical orthodontics it was impossible to assess the effects of this variable. As noted several patients exhibited an anterior movement of point B post surgically, when these were examined closely it was found that what had actually happened was that the mandible had rotated in an anticlockwise direction, possibly due to orthodontic tooth movement. Reitzik (1980) reported similar findings.

Only group II showed a statistically significant change with surgery of the mean lower incisor to mandibular plane angle and this was less than one degree. One would not expect the surgery to alter this angle significantly, unless the proximal segment was moved in the vertical plane relative to the distal segment. No groups showed any statistically significant changed in the mean lower incisor to mandibular plane angle. This implies that the position of the lower incisors was reasonably stable, although in the inverted 'L' groups one may have expected remodelling around the gonial angles to have caused a change in the lower incisor to mandibular plane angle and it may be that such a change did in fact occur but was masked by the gonial remodelling. Of note was the fact that the lower incisor apex was a difficult point to identify and was associated with the most variability in the horizontal plane during the double determinations (Section 12.1).

Small but statistically significant changes were seen in the inter incisal angulation post surgically in Group I and II presumably as the effects of orthodontic treatment.

The mean changes in the overbite and overjet with surgery reflected the planned surgical shifts. Post operative changes in overjet for Group I and II were statistically significant but less than 1.2 mm in magnitude. However there were individuals who exhibited up to 4 mm of overjet, clearly a less than ideal result for them. Mean changes in overbite post surgically were again statistically significant and were of the same order of magnitude and range.

15.6 MAGNITUDE OF MANDIBULAR ADVANCEMENT

With Group I this study found a positive correlation between surgical advancement and relapse, this is in agreement with most researchers, such as Will and West (1989). Many researchers, including Kierl et al (1990), found a strong correlation between advancement and relapse whereas this study found only a weak correlation.

Groups II and III showed a weak negative correlation between magnitude of advancement and relapse, this can probably be explained by the small sample size resulting in a result which is not significant. Care needs to be taken in interpreting results because of the small sample sizes, as misleading correlations known as "specious associations" may result. (Brown 1973)

It is noticeable that in Group III where the largest mean advancement took place that the horizontal relapse is proportionately much larger than that seen in the other groups, this supports the findings of Will and West (1989).

15.7 CONDYLAR POSITION

The patients in Group I had the condyle held in the fossa by the application of a miniplate from the maxilla to the proximal fragment prior to completion of the cuts, similar to the method described by Van Sickels et al (1990). Initially the centric relation position was located by manually positioning the mandible intraoperatively into its most retruded position, after several cases were treated by this method it was decided to use a centric relation wafer constructed preoperatively by getting the patient to bite into a registration material in the most retruded position. It was felt that the latter method gave a more positive location as without the presence of a wafer unstable occlusal contacts were likely to move on completion of the osteotomy cuts.

The patients in Groups II and III had the condyles seated manually prior to rigid fixation by gently pushing the proximal fragments postero superiorly. On several occasions with Group II patients, once IMF was released, the pre planned position had not been achieved presumably because of condylar distraction and accordingly fixation had to be removed and reapplied once the condyles had been reseated.

All of the patients in all three groups had rigid fixation between the proximal and the distal segments and none were placed into intermaxillary fixation postoperatively. Any condylar distraction should thus have been apparent intraoperatively and would have been corrected.

The horizontal and vertical movements of the hinge axis give an idea of condylar position, however landmark identification in this area was difficult due to superimposition of structures. This supports the findings of Chate (1987) who found difficulty in accurately locating landmarks around the ares of the petrous temporal bone.

With the intraoral inverted 'L' group there was no mean significant changes in either the vertical or horizontal position of the hinge axis with surgery, although individuals did show changes. The bilateral sagittal split group also showed no mean significant change with surgery. In contrast however group III showed significant changes in both the horizontal and vertical.

To limit condylar movement with surgery there is an argument for using a condylar positioning plate such as that described by Van Sickels (1990) even on extraoral inverted 'L' osteotomies and possibly on sagittal split osteotomies, the main disadvantage is the added surgical time and cost of the materials. These however are minor compared with the overall goal of achieving a successful long term stable operation.

Post surgically from T2-TL a small (0.8 mm) but statistically significant ($p < 0.05$) posterior movement of the hinge axis was seen in Group I. In Group II only a significant change for females where an inferior movement was noted. In group III a statistically significant ($p < 0.05$) change was only seen in the vertical where the hinge axis moved superiorly 2.1 mm . While it is quite possible that the changes noted in Groups I and III were due to condylar and glenoid fossa remodelling it is more likely that they are due to errors of the method. To accurately monitor condylar changes more accurate imaging would need to be used, such as C.T. scans.

15.8 PROXIMAL AND DISTAL SEGMENT POSITIONING.

When the mandibular plane to SN was measured, Group I showed a small significant increase with surgery, this is consistent with advancement of Class II patients with deep overbites. Group II showed an insignificant increase, again consistent with the surgical movements. Group III showed a significant decrease of over 12 degrees, this is consistent with the planned surgery which in this group was directed towards a counter clockwise rotation of the distal segment and hence the effect on the mandibular plane angle. These changes are reflected by an increase in posterior facial height although not statistically significant. Anterior facial height showed a statistically non significant increase, this was in part due to the genioplasties which were advancements combined with vertical augmentations.

Following surgery no mean postoperative change in mandibular plane angle was noted for Group II, this is in contrast to Groups I and III where the angle increased a significant amount. This implies either there was inter-fragmentary movement or remodelling changes. The latter is most likely as a marked rounding of the gonial angles was evident in almost all the inverted 'L' patients, this has been noted by Reitzik (1980). Interestingly Barer (1987) found no changes to the gonial angles in his series of inverted 'L' patients. The findings relating to Group III support the findings of various authors such as NcNeil et al (1973), Epker et al (1978) and Gassman et al (1990) that anticlockwise rotations of the distal segment increase the rate of relapse.

Mean anterior facial height was increased by surgery for all groups but was only statistically significant for Groups I and II. Following surgery the only significant mean change was seen in group II which showed a slight increase, again individuals however showed a range of changes. The results indicate that mean anterior facial height is relatively stable post surgically. A problem with measuring anterior face height in this study is that Menton is affected when a genioplasty is performed. Subsequent changes may then be due either to remodelling of the chin or movement of the distal segment.

No statistically significant changes were seen with surgery in the mean posterior facial height. Following surgery Group II showed a small but statistically significant increase, whereas Groups I and III showed decreases in posterior facial height, only Group I however was statistically significant. Again it is likely these changes in Group I were due to loss of the gonial angles.

The mean distance MI (y) vertical showed an increase in all groups as a result of the surgery. Post surgically there were no statistically significant changes in any of the groups. This result supports the idea that the changes seen with the mandibular plane angle and the posterior facial height for Groups I and II were due to gonial angle remodelling.

Groups I and II both showed an increase in the gonial angle with surgery however only Group II was statistically significant. Group III showed a large significant decrease in gonial angle, again reflecting the planned anticlockwise rotation of the distal segment. Post surgically the only significant change seen was in Group I where a statistically significant increase was seen, probably as a result of gonial angle remodelling.

The only significant mean change seen in ramal angle (SNArGo) due to surgery was in Group II where a decrease was noted, this may have occurred because no condylar positioning plate was used. Interestingly in Group I where a condylar positioning plate was used, although there was no mean change, there was individuals who showed change to ramal angle. This could reflect the limitations of the method or perhaps point to failure of the condylar positioning plate to rigidly hold the proximal segment. Mertens and Halling (1992) have suggested reinforcing the condylar positioning plate with acrylic resin to improve its rigidity.

Following surgery statistically significant changes were seen in Groups I and II in the mean ramal angle (SNArGo) with Group I showing a decrease and Group II a very small increase. The changes in Group I were consistent with gonial angle remodelling.

15.9 SUBMANDIBULAR CHANGES

In this study hyoid position was assessed by identifying the most superoanterior point on the body of the hyoid bone and relating this to the S-SN7 line, this is a reflection of tongue posture. (Greco et al 1990)

All groups showed a statistically significant mean anterior movement of the hyoid bone with surgery, this was greatest in Group III which also had the greatest advancements of point B. Post operative changes for Group I and II were not statistically significant, Group III showed a posterior movement of the hyoid bone which was significant and the magnitude of which was almost half that of the original advancement. Wickwire (1972) investigated the position of the hyoid bone following mandibular set back procedures and found the reverse, that is with setbacks the hyoid was moved posteroinferiorly with surgery and then with time tends to return to its original position, although it does not completely regain its original position.

In the vertical plane there were no statistically significant mean changes with surgery for any group and post operatively the only significant change was found in Group III where the hyoid bone moved inferiorly with time 3.4 mm. Ching (1995) found with mandibular set back osteotomies that the hyoid bone occupied a more superior position postoperatively relative to its preoperative position. Ching postulated that the tongue readapted by moving vertically to occupy more of the space in the mouth and thus maintain the hypopharyngeal airway. It would seem that in Group III the reverse has happened, that is with large mandibular advancements there is more room for the tongue to occupy an inferior position and hence the hyoid bone moves inferiorly.

15.10 PHARYNGEAL DEPTH

Groups I and II showed statistically significant increases in the mean pharyngeal depth horizontal with surgery, whereas although Group III showed a mean increase of 2 mm this was not statistically significant. Although for all three groups the mean change was an increase, there was a wide range for all groups with each group showing at least one value which was a decrease. This implies that a mandibular advancement cannot be relied upon to increase the anterior-posterior dimension of the pharyngeal airway. Following surgery there were no statistically significant changes seen for any group.

These results cannot be directly compared to maxillomandibular advancements for the treatment of sleep apnoea such as that reported by Waite et al (1995). These authors reported a 7.8 mm increase in posterior airway space in a study of 15 patients 6 months postoperatively. The patients selected for maxillomandibular advancements in their study all suffered from sleep apnoea and their cephalometric profiles are likely to be significantly different to any of the groups in this study. The surgery itself is significantly different as the patients had bimaxillary advancement and genial tubercle advancements, the mean mandibular advancement was 10.3 mm. The method used by Waite et al ((1995) to assess posterior airway space is also different to the method used in this study, they measure the airway at the level of the lower border of the mandible which is at a higher level than that measured in this study.

The pharyngeal depth vertical showed statistically significant mean changes with surgery in Groups I and II, the depth decreased which means that APw moved superior with respect to PPw. Postoperatively the only statistically significant mean change was seen in Group II with an increase less than the original shift being seen. There were no statistically significant changes seen in Group III. The vertical changes seen do not seem to show any obvious pattern compared to the movements of the hyoid bone.

15.11 COMPLICATIONS

The absence of any intraoperative uncontrolled haemorrhage is in agreement with other studies such as Van de Perre et al (1996), who found no major problems with haemorrhage for mandibular surgery and a very low incidence of problems due to haemorrhage for bimaxillary surgery. Van Merekesteyne et al (1987) also reported the incidence of problems with haemorrhage as two problems in a series of 161 mandibular osteotomies.

The most significant complication seen was the facial nerve palsy occurring in a patient in Group III, fortunately this resolved spontaneously. Due to the fact that all branches were involved, the most likely explanation was that the proximal fragment was rotated in a clockwise direction thus applying direct pressure to the main trunk of the facial nerve. Piecush and Lewis (1982) described a similar complication occurring with a bilateral sagittal split osteotomy advancement, it also resolved spontaneously. A traction injury from a retractor would be more likely to affect only the lower branches. Perhaps the use of a condylar positioning plate may have prevented such an injury. The lack of any permanent facial nerve lesions is in agreement with the findings of Jones and Van Sickels (1991) who stated that the incidence of permanent facial nerve injuries with mandibular osteotomies is extremely low.

The incidence of infection in Group I is higher than that reported in the literature for mandibular osteotomies such as that by Van de Perre et al (1996). It would seem likely that the presence of the free bone graft may increase the incidence of infection, however a larger sample would be needed to confirm this.

There were no cases of intraoperative accidental sectioning of the inferior alveolar nerve, again this is in agreement with Van Merkesteyne et al (1987), who found no cases of lesions of the nerve in vertical ramus osteotomies and a relatively low incidence with the sagittal split osteotomy.

15.12 NEUROSENSORY FUNCTION

In this study the only patients who subjectively reported altered sensation of their lower lip or chin were in the sagittal split group. This supports the findings of Naples et al (1994) who found that bilateral sagittal split patients were more likely to report hypoaesthesia of the lower lip and chin.

Objective testing revealed a statistically significant difference between the intraoral inverted 'L' osteotomy group and the bilateral sagittal split osteotomy group ($p < 0.05$). This differs the with findings of Naples et al (1994) who found no statistically significant difference between the inverted 'L' and bilateral sagittal split osteotomy when used for setbacks. Naples et al did however find that the variances of the BSSO group were much greater than the inverted 'L' group. This implied that the results after the BSSO were more erratic.

Some researchers would argue that objective tests used in this study are in fact the patients subjective response to objective stimuli. Hearn (1995) stated that an easily applied objective test is not yet available to monitor sensory loss, however two point discrimination is a useful test to detect the presence of a nerve injury. Pogrel (1990) stated that pinprick and two point discrimination are two of the tests most likely to reveal nerve damage, as these features are lost first.

Unfortunately not all patients in the groups were tested. Further investigations need to be carried out in this area to confirm these findings and to establish what the incidence of nerve injury is with the inverted 'L' osteotomy.

VI

CONCLUSIONS

CHAPTER 16

CONCLUSIONS

1. The inverted 'L' osteotomy can be performed safely and easily via an intraoral approach.

2. No significant difference in relapse was found between the intraoral inverted 'L' osteotomy or the bilateral sagittal split osteotomy.

3. This study shows that the amount of relapse for an individual following mandibular advancement is variable and unpredictable with either the inverted 'L' or bilateral sagittal split osteotomy.

4. This study shows that the incidence of both objective and subjective neurosensory changes were lower with the intra oral inverted 'L' osteotomy when compared to the bilateral sagittal split osteotomy.

5. There are marked changes in the gonial angles with the inverted 'L' osteotomy with a permanent rounding of the gonial angles in most cases. This occurs is first noticed several weeks post operatively.

6. The Intraoral inverted 'L' osteotomy is a straightforward osteotomy with major benefits of maintaining lip sensation, thus minimising morbidity and medicolegal risk.

VII

APPENDIX

APPENDIX

SHEEP EXPERIMENT

INTRODUCTION

To investigate biomechanical and histological issues relating to the inverted 'L' osteotomy it was decided to develop an animal model. Other reseachers, such as Suuronen et al (1992), have used sheep for investigating bone healing across osteotomy sites. The aims of the study were to investigate: bone healing, bone grafting and internal fixation following bilateral inverted 'L' osteotomy in the sheep.

METHOD

Ethics approval was first obtained from the Institute of Medical and Veterinary Science, (Ethics reference number 80/94). A mature Australian Merino sheep weighing approximately 60 kg was used. Anaesthesia was induced with intravenous injection of thiopentone sodium into the external jugular vein. Intubation was performed, and anaesthesia was maintained with isoflurane/ N_2O/O_2.

The skin around the mandibular angles was shaved and draped in a sterile manner. A skin incision approximately 6 cm long was made just below the lower border of the mandible in the region of the angle. Blunt dissection was then carried out until the inferior border of the mandible was reached. The attachment of the masseter muscle was reflected exposing the mandibular ramus. An inverted 'L' osteotomy cut was performed above and behind the lingula (Figure appendix 1) using a bur with water irrigation. Once this was completed on the first side it was repeated on the remaining side, resulting in the distal segment being freed from the two proximal segments.

The distal segment was advanced 5 mm, so that the molar cusps still reasonably interdigitated. The segments were then fixated with three Wurzburg mini plates per side. One plate was placed across the anterior part of the horizontal cut, one was placed on the inferior part of the vertical cut and the remaining plate was placed horizontally across the vertical cut midway along its length.

A bone graft was harvested from the buccal plate on each side of the distal segment and these cortico cancellous chips were placed in the defect created in the vertical cut. The bone graft was only placed in the inferior half of the vertical cut, the superior half having no bone graft. The wounds were closed in layers with resorbable sutures. The animal was given post operative pain relief and commenced on a soft diet the following day. Six weeks post operatively the animal was sacrificed with a lethal injection of thiopentone sodium i.v. into the external jugular vein. The mandible was dissected out and visually examined, the mandible was sectioned through the symphysis menti and radiographs were taken of each side. (Figure appendix 2) The plates were removed and each side was subjected to stress testing, by holding the condyle in a vice and loading the incisors with a known force.

Blocks of bone were taken from one side, across the region where the vertical osteotomy had been made. One block from a bone grafted region inferiorly and one block from an ungrafted region. The blocks were decalcified and sectioned, the sections were then histologically prepared and stained with haematoxylin and eosin and examined under a light microscope.

Figure appendix 1 Sheep mandible showing placement of inverted 'L' cuts

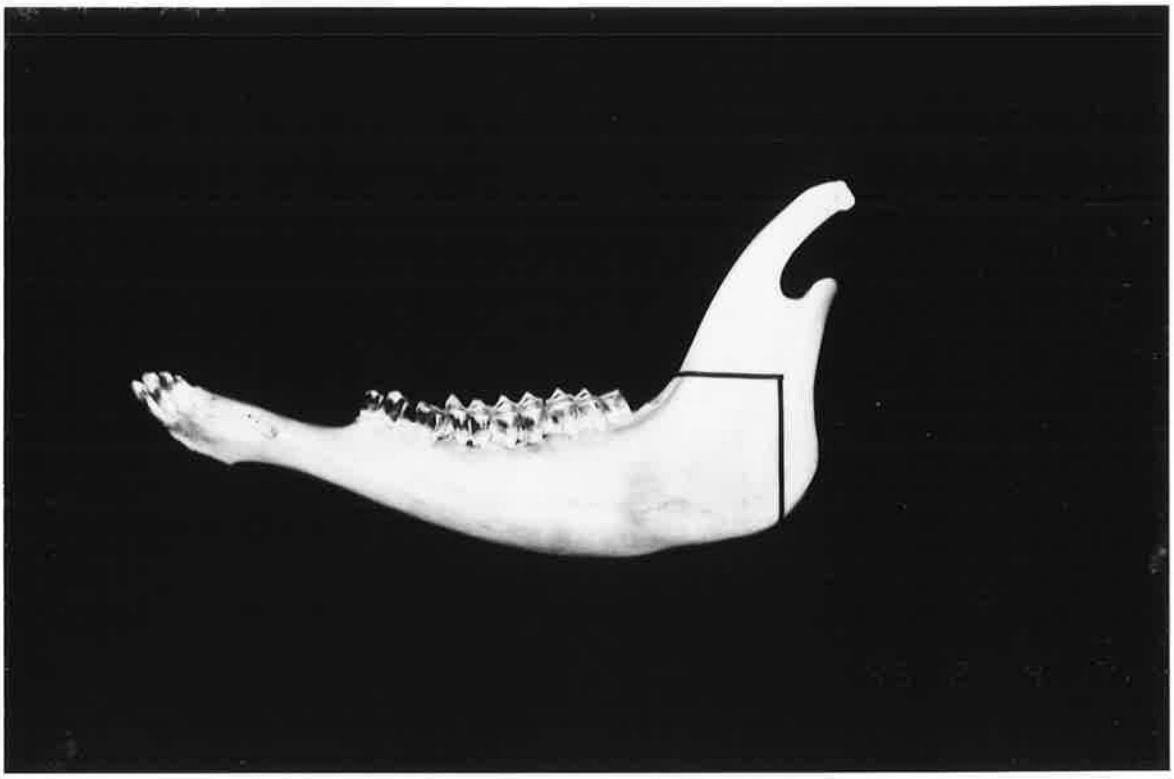
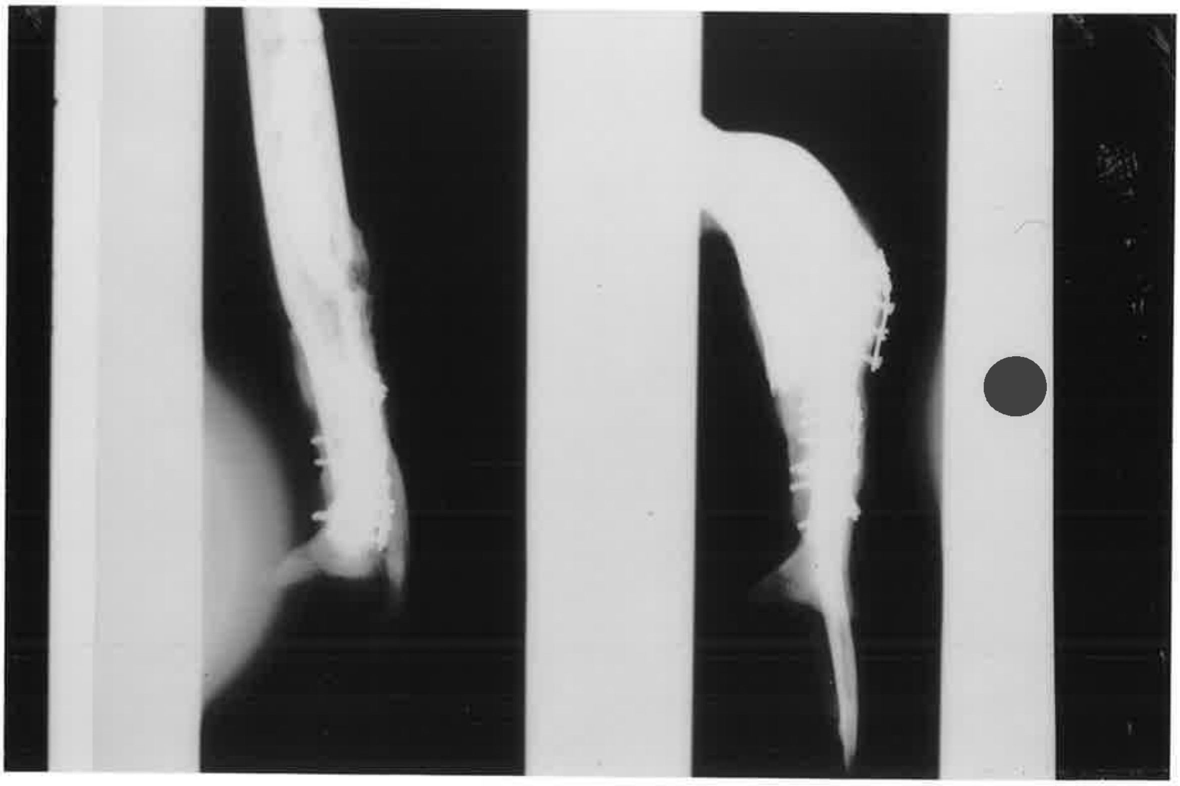


Figure appendix 2 Radiographic appearance of sheep mandible post mortem.



Results

The mandible was found to have healed with a solid union across the osteotomy cuts, however it was noted that on the right side the two superior plates had fractured. (Figure appendix 3) The plates on the left side were intact. All screws appeared firm and there was no obvious signs of infection.

Each side of the mandible withstood a force of 200 N applied to the incisor region, however when forces greater than this were applied it resulted in the condyle being crushed by the jaws of the vice and the stress testing had to be abandoned. The osteotomy sites did not fail.

The blocks of bone were taken from the left side of the mandible and examined under a light microscope.

Appearance of bone grafted site:

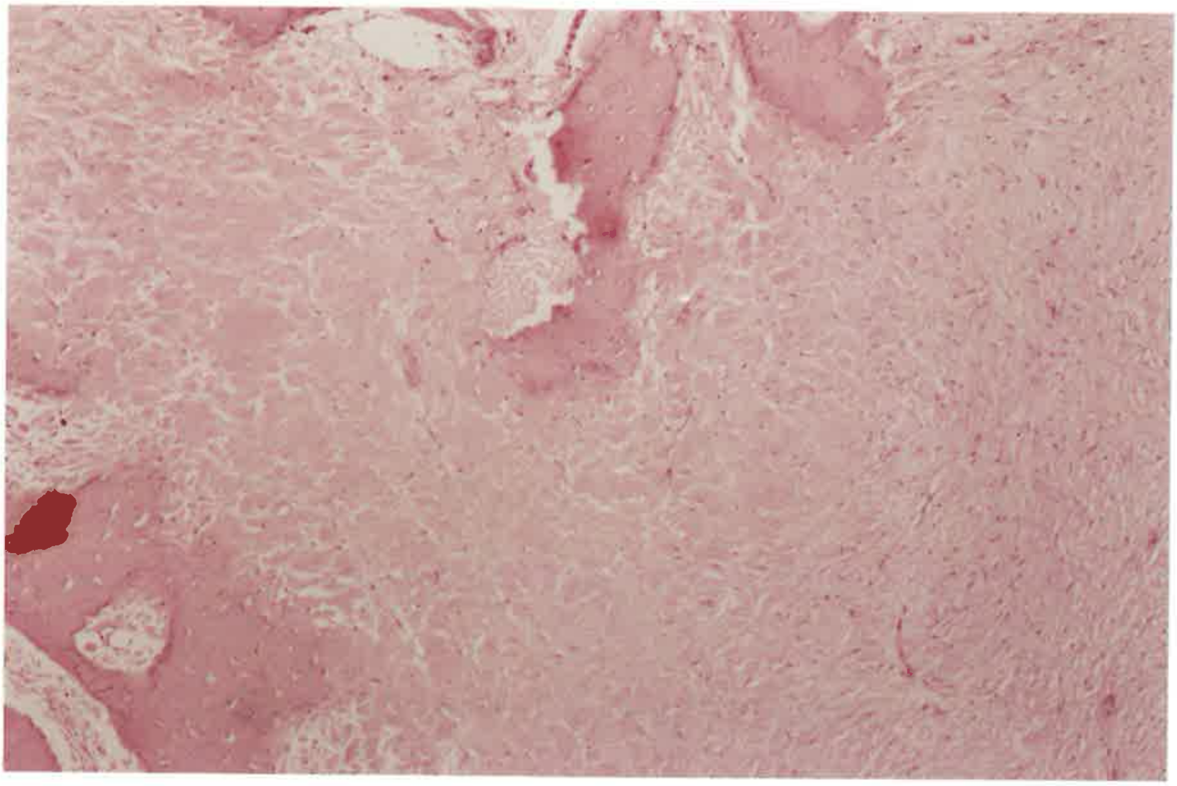
Microscopic examination showed there was fibrous union characterised by non inflamed densely collagenous fibrous connective tissue, with trabeculae of new bone on either side of the osteotomy cut. Small fragments of non vital bone, possibly representing the original bone chips are evident on the extremity of the defect. (Figure appendix 4)

Appearance of non bone grafted site:

Microscopic examination showed a small contour defect in the area of the osteotomy. The outline of the original bone cut could be delineated abutting a

Figure appendix 3 Radiographic appearance of hemimandible showing fractured plates.

Figure appendix 4 Photomicrograph of bone grafted site.



meshwork of fine trabeculae of immature bone characterised by osteoblastic rimming, many lacunae, evidence of remodelling and lamellation. The defect was entirely bridged with immature bone (Figure appendix 5).

DISCUSSION

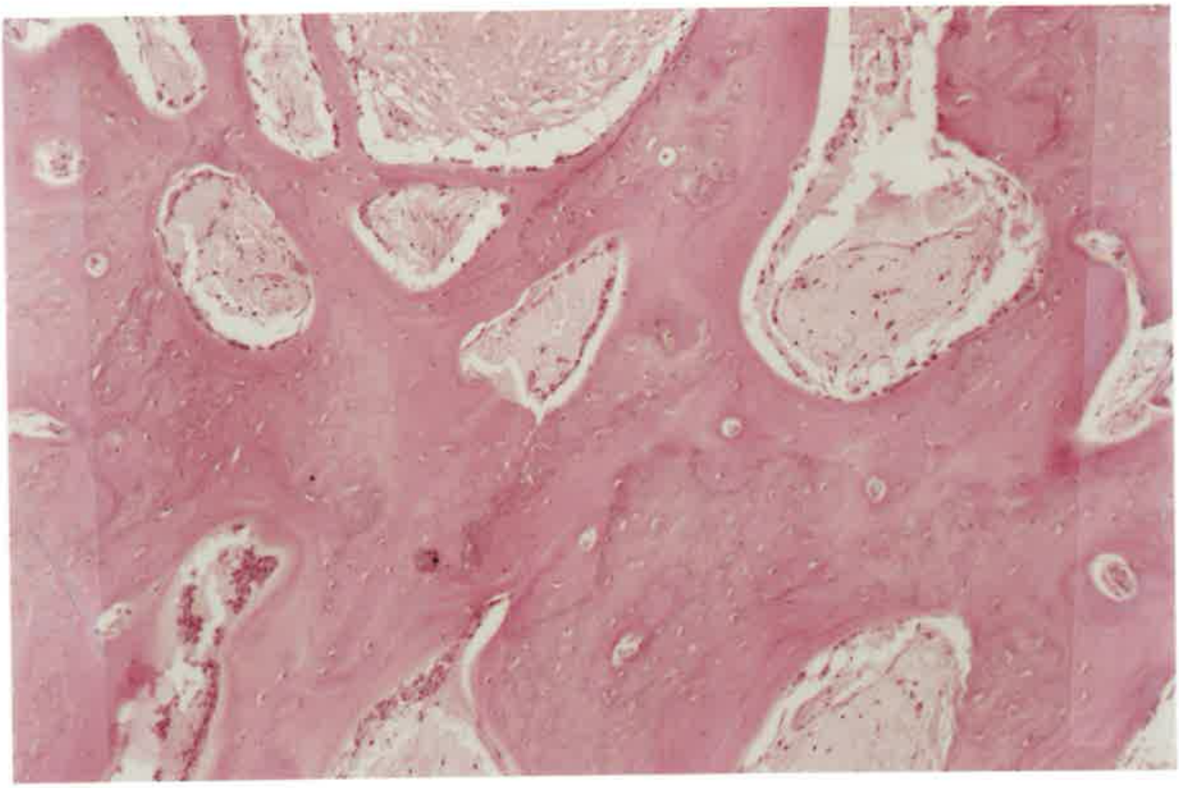
The sheep experiment demonstrated that the sheep is a suitable animal model for investigation of the inverted 'L' osteotomy.

The fact that two plates fractured indicates that the forces on the plates are significant and imply that the pattern of strains on the sheep mandible is similar to the humans as described by Champy et al (1978). With tensile stresses along the anterior border of the ramus and along the alveolar border. The main problem encountered while stress testing the hemi mandible was holding the specimen. Wittenberg et al (1997) embedded the mandibular condyles in acrylic resin and used a custom built holding device to hold the ramus. Further biomechanical investigations are required to investigate the magnitude and directions of these forces.

The histology results were surprising in that the non grafted side appeared to have healed better than the grafted side. One would have expected the graft to have facilitated healing rather than hinder it. This may relate to the fact that the graft was compact cortical bone with little cancellous marrow; the effect of different biomechanical strains in different regions of the ramus or both. Further animals sacrificed at different time intervals are required to determine these issues.

The experiment did not proceed further as the research support grant was not forthcoming within the time frame of this study.

Figure appendix 5 Photomicrograph of non bone grafted site.



VIII

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