# THE LE FORT I DOWNSLIDING OSTEOTOMY: A STUDY OF LONG-TERM HARD TISSUE STABILITY

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A research report submitted to the Faculty of Dentistry, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Dentistry.

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## DECLARATION

I, Ziv Steve Wagner declare that this thesis is my own work. It is being submitted for the degree of Master of Science in Dentistry in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Fifteenth day of April 1998.

I dedicate this work to my family and friends

who supported me

at this, the hardest time of my life.

## ABSTRACT

Surgical maxillary repositioning in individuals with a vertical maxillary deficiency, may be accompanied by skeletal instability. Cephalograms of 10 patients who underwent a Le Fort I downsliding osteotomy were studied retrospectively. 7 patients underwent a single jaw procedure while 3 patients underwent a double jaw procedure. Rigid fixation was used in 7 patients while wire osteosynthesis was utilised in 3. Descriptive statistics, Pearson moment correlations, and significance testing were performed at the 5% significance level. The intra-observer error reflected by the 95% confidence limit of measurements, ranged between 0.76 and 1.27 mm, and 0.83°. The maxilla was stable horizontally but it underwent a mean 32.1% superior relapse anteriorly, at the long-term. The results were however variable. Single jaw surgery and rigid internal fixation showed no difference in stability than with wire osteosynthesis. Bimaxillary surgery with rigid fixation showed no difference in stability to isolated maxillary surgery and rigid fixation.

## ACKNOWLEDGEMENTS

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## 1.0 INTRODUCTION

Disproportions of the tooth bearing segments of the jaws and the associated soft tissues are diverse. Affected individuals may seek treatment on the basis of one or more of the following reasons: a displeasing facial appearance, a malocclusion, and a reduced ability to function. The origin of corrective maxillo-facial surgical techniques was traced one hundred and thirty-five years back.[1] Since then, surgical procedures have evolved to improve treatment results. Various modifications of the original Le Fort I downgrafting osteotomy have been described for the more effective correction of midfacial deformities.[2, 3, 4, 5, 6, 7]

There is a lower incidence of non-cleft patients with a vertical maxillary deficiency in comparison to other dentofacial deformitis.[2, 8, 9] Such patients usually exhibit a decreased lower facial height, often combined with an anteroposterior maxillary deficiency, causing little or no exposure of the maxillary incisors and a class III malocclusion.[2] The freeway space is frequently increased and in severe cases it may be as great as 10 to 15 millimeters.[2, 10] The Le Fort I downgrafting and advancement osteotomy provides a surgical solution for this condition, however, skeletal instability that accompanies maxillary downgrafting remains a major concern.[2-4, 8, 11-14]

The Le Fort I downsliding osteotomy was described by Reyneke and Masureik in 1985.[4] The principle of this surgical technique involves the simultaneous correction of the horizontal as well as vertical deficiency of the maxilla. The horizontal Le Fort I osteotomy is angulated at a calculated angle, so that as the maxilla is advanced along this angulated osteotomy plane the vertical height is increased (Figure 1.0). The vertical change is limited to cases that require relatively small maxillary positional changes. Preliminary findings were encouraging for the technique.[4] The authors attributed the skeletal stability to a greater bony contact with relatively smaller areas of interpositional bone grafting.

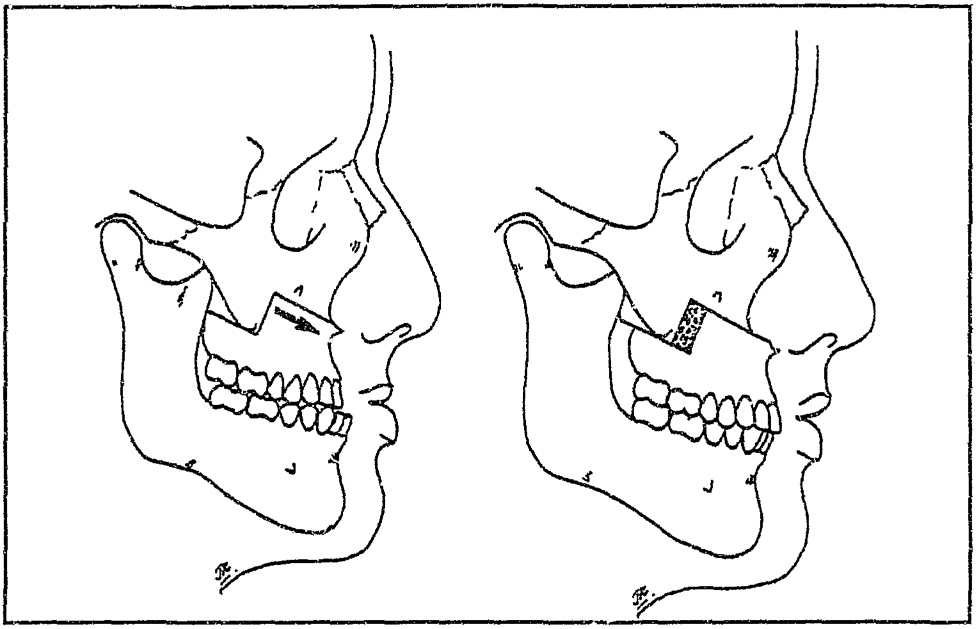

**Figure 1.0** A diagram illustrating the downsliding technique. The angulated osteotomy creates an inclined plane along which the maxilla is advanced and elongated. The inclined plane provides a good bony contact. A relatively small amount of interpositional bone graft is required.

A number of factors must be considered during the orthodontic-surgical management of individuals with a vertical maxillary deficiency:

## Orthodontic management

Orthodontic objectives are designed to facilitate surgery and minimise post-operative instability. When done improperly however, the potential risk of post-surgical relapse increases.[2] For optimum stability, the extrusion of posterior teeth should be avoided or discontinued three months prior to surgery.[2] The goal of post-surgical orthodontic treatment is to maximise the occlusion, often with guiding elastics. The use of heavy guiding elastics immediately post-operatively, may however place strain on the bone and the bone graft, at the sites of fixation.[8]

2. Method of stabilisation

Rigid stabilisation techniques have been introduced to counteract the muscular forces that might act on the mobilised maxilla.[2] Such innovations include threaded Steinmann pins,[7, 14] the intraoral fixation appliance,[2] and rigid internal fixation. The early advocates of rigid internal fixation believed that it enhances bone healing and improves skeletal stability.[13] Skeletal relapse was however reported in studies that utilised rigid internal fixation, to stabilise an inferiorly and/or anteriorly repositioned maxilla.[8, 12, 15, 16]

A number of researchers examined the difference in maxillary stability between rigid internal fixation and wire osteosynthesis, in patients that underwent a Le Fort I maxillary advancement and/or downgrafting. Proffit et al.[12] found less vertical relapse and more horizontal relapse in a group stabilised with rigid fixation, but the differences were not statistically significant. The findings may have been influenced by the fact that the authors included grafted and non grafted cases in their sample, and since a number of different surgeons performed the procedures. In a separate study, Proffit et al.[15] found a greater mean amount of superior relapse in the rigid fixation group. This group was however positioned inferiorly more than the wire fixation group, and the differences were not statistically significant. Cases from four different surgeons were included in the study.

Major et al.[17] on the other hand, found that a group of patients stabilised with rigid internal fixation were significantly more stable vertically, at the anterior maxilla, than a group stabilised with wire osteosynthesis. The authors found no significant difference in stability at the posterior aspect of the maxilla, between the groups. Each of the respective groups were however operated-on by a different surgeon and the sample included patients with one piece or segmental maxillary surgery, with or without a combined bilateral sagittal split osteotomy. The authors did not present horizontal skeletal changes that may have occurred.

Ellis et al.[16] performed maxillary downgrafting on monkeys and found that the group stabilised with rigid internal fixation demonstrated the best maxillary stability, while the wire fixation group was the least stable. The rigid fixation group nevertheless underwent a mean 30% superior relapse. Factors that should be considered when interpreting the results of this study include: anatomic and functional differences from humans, a short follow up period, a relatively high infection rate, a large amount of surgical downgrafting, and an inability to teach the animals avoidance of high occlusal forces post-operatively.

Wilmar[10] reported little vertical relapse in five female patients that underwent a significant amount maxillary downgrafting (a mean 9.8 mm at the anterior maxilla). and were stabilised with wire osteosynthesis. The three-year maxillary stability was assessed from a radiographic examination of surgically placed maxillary implants.

de Mol van Otterloo et al.[9] examined the one-year vertical stability of the maxilla in four groups of patients, that underwent a maxillary downgrafting and an anterior interpositional bone graft. The single jaw with wire osteosynthesis group underwent little vertical relapse one year post-operatively. The authors concluded that this procedure has a predictable vertical maxillary stability. They found that patients from a group that underwent double jaw surgery and rigid internal fixation were more stable than those of two groups that underwent double jaw surgery and wire osteosynthesi The findings of the study were that rigid internal fixation improves the outcome of double jaw cases. No statistically significant differences in stability were reported.

According to the above mentioned reports, rigid internal fixation does not necessarily offer a better stability than wire osteosynthesis, nor does it provide a fail-safe method of stabilisation, especially when the maxilla is positioned inferiorly.[8, 13, 18, 19]

### 3. Bone grafting materials

The placement of rigid grafting materials is thought to improve stability when the maxilla is moved inferiorly and/or anteriorly.[12] The graft might serve as a mechanical reinforcement to help absorb the compressive masticatory forces, or as a means of assisting the healing at the osteotomy site[12, 18]. These presumptions are not conclusive however since variable findings were reported.[6, 12] Proffit et al.[12] found that the presence or absence of autologous or homologous grafts had no effect on stability. Quejada et al.[3] found 24% relapse, six months post-operatively, in cases that were downgrafted a mean 8.9 mm and were stabilised with wire fixation and autologous bone grafting. Their study design inappropriately included the upper central incisal tip as an indicator of maxillary skeletal position. Their sample was composed of patients with mandibular ramus and genioplasty procedures. Wardrop and Wolford[18] found minimal relapse with the use of porous block hydroxyapetite implant material and rigid internal fixation, following maxillary downgraft and advancement. They however examined a mixed sample that included patients that underwent a previous repair of a cleft palate, mandibular advancement, mandibular setback, and bilateral TMJ reconstructions. The authors inappropriately used the upper central incisal tip and mesial cusp of upper first molar to indicate maxillary skeletal changes.

The majority of the studies that utilised different bone graft materials included a number of complicating variables. It is therefore difficult to directly comment about the extent to which the placement of an interpositional bone graft may assist stability, or to compare the effectiveness of different graft materials in controlling post-operative relapse.

### 4. Double vs. Single jaw surgery

It was reported that by performing a double jaw procedure the overall stability of the maxilla and/or mandible may be improved.[12, 15, 20, 21] It is possible that lengthening of the elevator muscles is thereby avoided at surgery thus increasing the probability of a stable post-operative outcome.[15, 19] de Mol van Otterloo et al.[9] however, found a greater vertical maxillary instability for two groups of patients that underwent a double jaw procedure and wire osteosynthesis, as compared to a group of patients that underwent a single jaw procedure and wire fixation. A group of patients that underwent a double jaw procedure and rigid internal fixation, had a similar vertical maxillary stability to the latter group.

A number of researchers failed to demonstrate statistically significant differences in maxillary stability between single and double jaw procedures.[3, 9, 15, 18, 20] According to these reports the conviction that one could improve the stability of a downgrafted maxilla by performing a concomitant mandibular osteotomy is therefore scientifically unfounded.

5. Neuromuscular factors

The adaptive behaviour of the jaw musculature following inferior and/or anterior maxillary repositioning, may contribute to post-operative instability.[2, 3, 8, 12, 16, 19] Due consideration is given to the freeway space and the physiologic rest position of the mandible.[2, 14] When the maxilla is downgrafted by an amount that exceeds the freeway space, this results in a clockwise rotation of the mandible and the stretching of the mandibular elevators.[19] Such an amount of stretch beyond the physiological resting length may not be well tolerated. The muscle fibres and their connective tissues might return actively, in variable amounts, to their initial resting length.[2]

Vertical maxillary deficient patients usually present with an increased freeway space into which the maxilla can be downgrafted.[16] In some clinical cases therefore, it may be possible to downgraft the maxilla by a relatively large amount without excessively stretching the elevator muscles. This however does not guarantee that muscle behaviour will not change and promote skeletal relapse. The mandibular elevators might in fact generate greater masticatory forces when stretched within their physiological limit.[2]

Throckmorton et al.[22] outlined the importance of facial morphology to an individual's ability to generate bite forces. Vertical maxillary deficient individuals may have a greater mechanical advantage of their jaw elevators. They might generate greater masticatory forces than long faced individuals. The functional advantage of the jaw elevators may change, as a result maxillary downgrafting. In such a situation the muscles may experience a reduced ability to generate optimal forces.[22]

A number of techniques have evolved to quantify muscle function. Strain gauges are used to measure isometric bite force, while muscle activity levels can be measured using electromyography, and by measuring both parameters simultaneously, it is possible to estimate masticatory force.[23] The validity of these techniques has not been established however.[24] Thus, although muscular adaptation to surgical intervention may be an important determinant of post-operative stability, the subject is not well understood.[24]

In order to reduce the distracting influence of the mandibular elevator musculature, it was proposed to induce muscle lengthening by stretching them prior to surgery, or to detach these muscles at surgery.[2]

- *Interocclusal conditioning appliance*

This is essentially a bite-opening appliance that is worn by the patient for several weeks prior to the surgery. The procedure is aimed at conditioning the muscles to the expected surgical increase in their length, in order to reduce the muscular forces post-operatively.[2] There is a lack of clinical research to support the significance of such an appliance. Ellis et al.[16] examined a group of adult monkeys that were fitted with a 12 mm bite opening-appliance, cemented to the maxillary teeth. The appliance was placed 12 weeks prior to the maxillary downgrafting and was removed just before surgery. The maxilla was stabilised with interpositional bone and wire osteosynthesis. The authors found that the appliance produced an orthopaedic effect, displacing the maxilla approximately 1 mm superiorly and 2 mm anteriorly. The stability of this group was better than the wire fixation group, but worse than the rigid fixation group. The authors concluded that the interocclusal bite-opening appliance may be a useful adjunct to reduce post-operative relapse. Two of the animals in this group however developed a post-surgical infection that necessitated surgical intervention. The amount of inferior repositioning was very large, and the follow-up period only twelve weeks. Clearly, controlled clinical studies must be done to support the importance of such an appliance.

- *Elevator muscle myotomies*

The detachment of the pterygoid, masseter, and temproalis muscle insertions, allows for the downgrafting of the maxilla without the stretching of the muscles.[2, 16] The muscles appear to reattach post-operatively at different insertion sites, while maintaining their preoperative length.[2] The procedure may be followed by resorption at the detachment sites and this may enhance facial aesthetics.[2]

The importance of this technique in improving post-operative stability was not conclusively demonstrated. Clinically acceptable results were obtained without the use of muscle detachment.[3] Ellis et al.[16] addressed this issue in their animal experiment. One group of monkeys underwent a bilateral coronoidectomy and detachment of the pterygomasseteric sling, and were stabilised with interpositional bone grafts and wire fixation. This group demonstrated a similar stability to the group that received an interocclusal appliance. The authors concluded that a muscle myotomy should be considered an adjunct in preventing post-operative relapse. Because of the limitations of this study however, more controlled studies should be undertaken to address this issue.

### 6. The amount of inferior repositioning

The planned amount of vertical maxillary repositioning is generally dictated by the required increase in maxillary incisor exposure. Special consideration is given to the accompanying increase of upper lip length, and the anticipated amount of relapse.[2, 11]

It is reasonable to assume that the greater the amount of the downgraft, the greater the dependence on the mechanical support of the graft material and the mode of fixation to maintain skeletal stability. This assumption cannot be verified from the findings of existing studies. Baker et al.[8] found that eight patients with 5 mm or more maxillary downgrafting experienced relapse, whereas only one patient with 5 mm or less downgrafting experienced relapse. Their sample was however mixed and included patients with segmental maxillary osteotomies and mandibular setbacks. Proffit et al.[12] found that in 75% of the patients in whom the maxilla was positioned inferiorly, more than 1 mm of superior relapse occurred. They reported that the more the maxilla was moved down, the more it tended to relapse upwards. The authors however did not furnish further statistical information to support this finding.

Several researchers reported that the measurable amount of vertical relapse is not related to the amount of surgical downgraft. Quejada et al.,[3] Persson et al.,[6] Bell and Scheideman,[11] and Wardrop and Wolford[18] found no significant correlation between the amount of surgical change and the amount of relapse. Ellis et al.[16] reported that a 12 mm surgical repositioning in their experimental monkeys was followed by a variable amount of relapse, twelve weeks post surgery (range 2 to 15.6 mm).

The issue of whether or not a larger amount of maxillary downgrafting is followed by a larger amount of relapse remains unsettled. Even small inferior maxillary movements may be prone to relapse.[8, 25]

A large amount of inferior maxillary repositioning in some individual patients, is perhaps insufficient to surpass the adaptive capabilities of the masticatory muscles.[3]

## 7. Surgical Technique

Various modifications of the Le Fort I osteotomy are available to facilitate the simultaneous anteroposterior and vertical movements of the maxilla. It is possible to reposition the anterior and posterior portions of the maxilla by different amounts. The height of the osteotomy cut and its angulation may be varied.[3, 4] It is possible that different osteotomy designs confer a different likelihood for post-operative maxillary relapse. This might be the end result of different bony interfaces created at osteotomy site,[3, 4, 5] or a difference in effect on the elevator muscles and their subsequent reaction.[3, 19]

Persson et al.[6] compared the maxillary stability of two groups of patients that underwent a maxillary downgrafting and advancement, and were stabilised with rigid internal fixation. Interpositional bone grafts were not placed and the osteotomy spaces were only covered by strips of cancellous iliac bone. In one group the whole maxilla was repositioned inferiorly. In another group only the anterior maxilla was repositioned inferiorly and bony contact was maintained in the posterior aspect of the osteotomy area. The latter group demonstrated a better mean vertical maxillary stability. Considerable confounding variables were however present in that study: six of the patients in the latter group (n=8) underwent a concomitant mandibular operation, one of the patients included in the study had a cleft palate, and all double jaw cases and three single jaw cases had intermaxillary fixation with suspension wires from the infraorbital rims to the mandible, the upper incisor tip was inappropriately used to measure the vertical skeletal maxillary changes. The authors attributed the better maxillary stability partly to the "clockwise rotation" of the mandible that accompanied the downgrafting, in patients that underwent a double jaw procedure. This is surprising since clockwise rotation of the mandible at surgery is generally thought to promote post-operative relapse.[3, 19]

No controlled clinical studies are available that allow a direct comparison between different Le Fort I osteotomy designs. Clearly, the findings of different studies may reflect on differences in surgical technique.

8. Surgical infection

Surgical infection may compromise the stability of a repositioned maxilla.[2, 19] Infection may occur at the osteotomy site where it may delay bone healing and accelerate bone resorption. An infection of the soft tissues surrounding the bone graft may prevent the rapid revascularisation of the bone, and may encourage soft tissue scarring and bony necrosis, thus promoting relapse.[2] It is therefore necessary to maintain a sterile surgical environment, to observe a careful manipulation of the tissues, and to copiously irrigate the osteotomy site. If an autologous graft is used it should be placed shortly after being harvested. Antibiotics are prescribed to prevent a possible infection.[2]

Most of the above mentioned studies can be criticised on the basis of a number of criteria, that make a direct comparison of their findings difficult: Two dimensional radiographs were used to evaluate three dimensional structures. A significant amount of error is commonly inherent in producing and analysing cephalograms.[26-28] The different experimental designs in the different studies reflect on the lack of standardisation of cephalometric analyses. Different authors incorporated different cephalometric landmarks and different reference planes to analyse possible changes. Different cephalometric landmarks such as ANS and Subspinale are not completely valid to assess skeletal maxillary movement.[9, 18, 26] However, unless implants are used, it is not correct to use dental landmarks to describe skeletal changes. The sample size was generally small in all studies. Some of the studies examined a mixed patient population incorporating cases with clefts, maxillary segmental procedures, multiple jaw operations, and different fixation methods. Some of the studies pooled cases that were operated on by different surgeons, or compared two different groups of patients who were operated-on by a different surgeon.[17] The follow-up period was different within and between the different studies. The lengthening of the mandibular elevator muscles was described in terms of the cephalometric changes to their skeletal attachments. It is however inappropriate to conclude about functional changes in muscle behaviour, from cephalometric radiographs alone.

This study was designed to evaluate the stability of treatment of the Le Fort I downsliding osteotomy. In an attempt to overcome some of the limitations of a cephalometric study, an anatomically stable cranial reference plane was used, and the amount of error was quantified and further reduced. A comparison of stability was performed between homogenous subsets of the total sample in respect of the mode of fixation, and the presence or absence of a sagittal split osteotomy.

## 1.1 Objectives of the Study

The purpose of this study was fourfold:

1. To evaluate the hard tissue stability of the LeFort I Downsliding maxillary osteotomy.
2. To evaluate a possible correlation between the surgical movement of the maxilla and any long-term change.
3. To evaluate the effect of the two fixation methods used.
4. To evaluate the effect of a coincident bilateral sagittal split osteotomy.

# 2.0 MATERIALS AND METHODS

## 2.1 The Sample

An ethical clearance certificate was issued by the University of the Witwatersrand Ethical Committee (Ref: R14/49 Wagner). A sample of ten was included in the study comprising of four males and six females (Table 2.1). All the patients were generally healthy and without a syndrome or a cleft lip or palate. The mean age of the sample was twenty years with a range of fifteen to thirty four years. The mean long-term follow-up period was fifteen months with a range of six to thirty three months.

Each of the individuals was diagnosed as having an anteroposterior and a vertical maxillary deficiency. Three of the patients were additionally diagnosed as having an anteroposterior mandibular excess. All the patients had undergone a Le Fort I downsliding osteotomy. Three patients also underwent a bilateral sagittal split osteotomy (BSSO), one of which also had a reduction genioplasty.

**Table 2.1** Summary of the data from the ten patients that underwent a Le Fort I downsliding osteotomy

| CASE NO: | SEX | AGE (Years) | LONG-TERM FOLLOW UP (Months) | FIXATION TYPE | SAGITTAL SPLIT OSTEOTOMY | GENIOPLASTY |
|---|---|---|---|---|---|---|
| 1 | F | 26 | 22.0 | RIF | NS | NS |
| 2 | M | 34 | 11.5 | RIF | S | NS |
| 3 | F | 15 | 6.0 | RIF | NS | NS |
| 4 | F | 18 | 7.0 | WIF | NS | NS |
| 5 | F | 20 | 13.5 | WIF | NS | NS |
| 6 | F | 17 | 15.5 | RIF | NS | NS |
| 7 | M | 16 | 33.0 | WIF | NS | NS |
| 8 | M | 20 | 9.5 | RIF | S | S |
| 9 | M | 18 | 20.5 | RIF | S | NS |
| 10 | F | 19 | 11.0 | RIF | NS | NS |

* NS= No surgery; S= Surgery
* WIF= Wire fixation; RIF= Rigid internal fixation

## 2.2 Surgical Technique

All the patients included in this study had undergone a Le Fort I downsliding osteotomy. Two angulated osteotomy cuts were performed to provide an inclined plane along which the maxilla was advanced and repositioned inferiorly.[4] The distal osteotomy cut was modified to follow the rotation of the occlusal plane of the mandible (Figure 2.2). The freeway space was clinically determined for each case prior to surgery and care was taken not to downgraft the maxilla by an amount that exceeded the physiological freeway space. The same surgeon performed the procedures on all the patients.

The positioned maxilla was stabilised using wire osteosynthesis in three patients and rigid internal fixation in seven patients. The former were placed in intermaxillary fixation for six weeks, while the latter were not immobilised but were instructed to eat a soft diet for four weeks. The mandible of the patients that underwent a bilateral sagittal split osteotomy was fixated with bicortical screws. Wire osteosynthesis was utilised at a time when rigid internal fixation was not yet available.

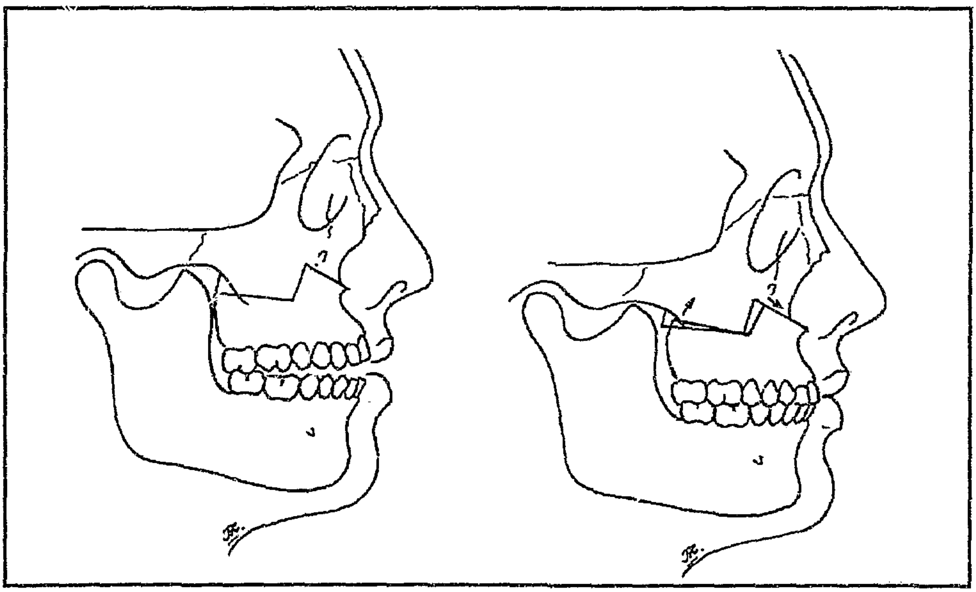

**Figure 2.2** A diagram illustrating a modification of the downsliding technique. The maxilla is rotated clockwise while undergoing a downsliding movement. The posterior length of the maxilla remains unchanged.

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J. P. Reyneke

## 2.3 Method

[illegible]al cephalograms of three time-intervals were obtained: T1 one week preoperatively, T2 one week post-operatively, and T3 long-term post-operatively (> 6 months). For each patient two preoperative cephalograms were taken to evaluate the exact vertical tooth to lip relation: one with the teeth in occlusion, and the other with the teeth apart and the lips in repose and slightly apart. The cephalograms were of good quality, all taken using a Panora cephalometer.

## 2.4 Cephalometric Method

A cephalometric analysis was designed for the study by the author, using the 'Viewbox' programme (version 1.9 developed by Demitrious Halazonetis, Athens, Greece). Seventy cephalometric points were located on each cephalogram. Four of the points (A, MxP, Is, Xc) were used for the analysis while the remaining points were used to transfer the cephalometric drawing (Figure 2.4). These points were selected for the fact that they are easily identifiable and reproducible. The cephalograms were traced on cephalometric tracing paper 0.025" in thickness, manufactured by the 3M company, using a 0.5 HB pencil. Each tracing was digitised using the Genius NewSketch 1212 digitising pad.

### *2.4.1 Cephalometric landmarks*

The three landmarks used to evaluate changes were (Figure 2.4):

1. Point A (Subspinale) - the deepest point on the curve of the maxilla between the anterior nasal spine and the dental alveolus, in the midsagittal plane.
2. Maxillary posterior point (Mxp) - a point on a line constructed 40 mm posterior to point A, midway between the inferior and superior cortical plates of the maxilla.[29, 30]
3. Incision superius (Is) - the incisal edge of the crown of the more anterior maxillary central incisor.

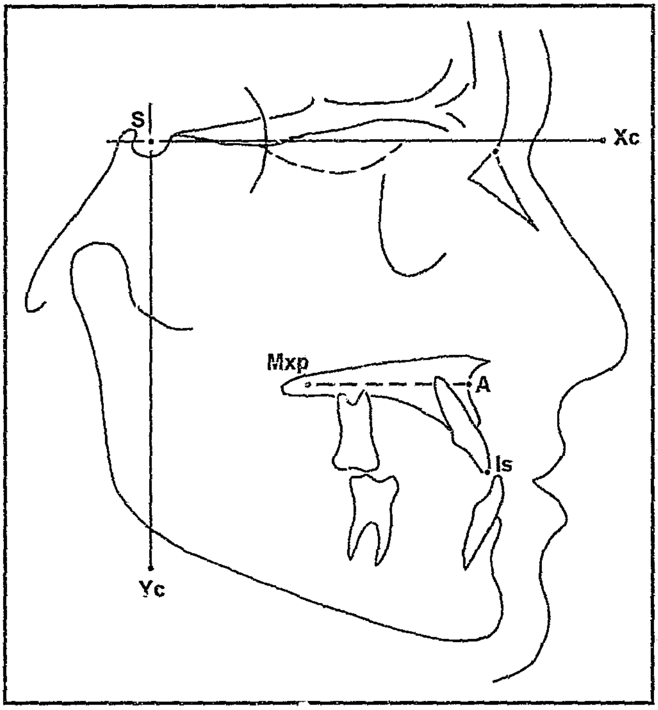


**Figure 2.4** The cephalometric landmarks and analysis with co-ordinate XY axes. Stable cranial structures are illustrated.

### *2.4.2 The tracing and superimposition method*

A template of the maxilla was traced from each preoperative cephalogram T1. This included as much of the internal architecture as possible. A pin-prick was made 40 mm posterior to point A, midway between the superior and inferior cortical plates of the palate, indicating point Mxp. By superimposing this template on subsequent cephalograms, points A, Is, and Mxp were located.

Points Sella and Nasion were traced from cephalogram T1. The outline of the anterior wall of sella, and areas in the anterior cranial fossa, i.e. planum sphenoidale, orbital roof, frontoethmoidal area, and the cribriform plate was traced from cephalograms T1, T2, and T3 (Figure 2.4). These areas are considered to be the most stable cranial structures.[27, 31]

A line was extended through Sella on tracing T1. This line was drawn manually, parallel to a line through points A and Mxp. A horizontal co-ordinate point Xc was marked on this line, outside the outline of the facial profile, at a fixed distance. The tracings of cephalograms T2 and T3 were individually super-imposed over the preoperative tracing T1. Care was taken to superimpose over the stable cranial structures. Points Sella, Nasion, and Xc were transferred from tracing T1 to tracings T2 and T3.

Each tracing was digitised four times and the computer programme projected an average value for the four readings. The programme extended a horizontal reference line through points Sella and Xc, and a vertical reference line through Sella perpendicular to Sella-Xc, to a fixed point that named Yc (Y co-ordinate; Figure 2.4). Serial tracings were thus superimposed over lines Sella-Xc and Sella-Yc. The surgical and long-term changes were noted relative to these co-ordinate lines.

## 2.5 Linear and Angular Parameters Measured

Landmarks A, Mxp, and Is were projected on co-ordinate lines Sella-Xc and Sella-Yc. The change of position of these landmarks was determined by the computer programme in the horizontal and vertical dimensions. The change in angulation of the palatal plane was evaluated by examining the angulation of a line joining points A and Mxp relative to the Sella-Xc line. This angle was named the Palatal plane angle (Ppa). All measurements were determined to the nearest two decimal points.

A ratio of absolute magnitude of change at the anterior aspect of the maxilla was calculated, using point A. This was performed to determine whether any specific ratio in amount of horizontal to vertical change of the maxilla performed at surgery, rendered a specific ratio of change at the long-term. The ratio of change was calculated for the two time intervals as follows:

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Viewbox, version 1.9

$$R1 = \frac{(T2 - T1)\,H}{(T2 - T1)\,V} \qquad R2 = \frac{(T2 - T3)\,H}{(T2 - T3)\,V}$$

*R1*- ratio of absolute amount of change at surgery (Surgical repositioning ratio).

*R2*- ratio of absolute amount of change at the long-term (Relapse ratio).

*T1*- value in mm of point A at 1 week preoperatively.

*T2*- value in mm of point A at 1 week post-operatively.

*T3*- value in mm of point A at >6 months post-operatively.

*H*- horizontal

*V*- vertical

## 2.6 Statistical Analysis

The statistical analysis was performed using the 'Statistix' computer programme (version 4.1 developed by Analytical software). Descriptive statistics were calculated for continuous parameters for the following time intervals: preoperatively to one week post-operatively (T1-T2), post-operatively to long-term (T2-T3). This was done for the total sample, as well as one group determined by the type of fixation, and another group determined by the presence or absence of a bilateral sagittal split osteotomy. The Man Whitney rank sum t test was performed to evaluate a possible significant difference for independent groups. The surgical repositioning ratio R1 and the relapse ratio R2 were compared for the total sample using a Student's paired t-test. The Pearson product moment correlation coefficient was used to assess a possible correlation between various parameters. Testing was performed at the 5% level of significance.

## 2.7 Measurement Accuracy

The replicated values of ten cephalograms were randomly picked out, one from each of the patients. Values for landmarks Xc, A, Mxp, Is, and the Palatal plane angle were assessed for combined accuracy of tracing and digitisation. Various parameters were calculated to demonstrate the degree of error inherent in the method. These included the difference between means, the standard error of the mean, standard deviation of the mean error, and the P value at the 5% level of significance.[26, 28] In order to examine the clinical application of the random error, the 95% confidence of a single measurement was determined.[26, 27]

# 3.0 RESULTS

## 3.1 Error of the Method

Intra-observer errors for the various landmarks are listed in Table 3.1. There were no significant differences between the first and second registrations for any parameter examined ($P > 0.05$). The difference between the means for the first and second registration ranged from 0.04 mm for the horizontal location of point Mxp to 0.28 mm for the vertical location of point Xc. The difference in respect of the Palatal plane angle was 0.07°.

The standard deviation of the mean error reveals that the random error was generally greater in the vertical dimension. Point MxP was the exception. The values for the horizontal dimension ranged from 0.54 mm for point Xc to 0.8 mm for point Is. The values for the vertical dimension ranged from 0.62 mm for point Mxp to 0.9 mm for point Is. The value for the Palatal plane angle was 0.59°.

The 95% confidence limit of a single measurement ranged from 0.76 mm for point Xc to 1.13 mm for point Is in the horizontal dimension. The values ranged from 0.88 mm for point Mxp to 1.27 mm for point Is in the vertical dimension. The value for the Palatal plane angle was 0.83°.

**Table 3.1** Intra-observer differences between double registrations of four landmarks and one angulation for ten cephalograms.

| | Mean 1 | Mean 2 | Difference between means | Standard error of the mean | Standard deviation of the mean error | 95% CI | P† |
|---|---|---|---|---|---|---|---|
| **Horizontal (mm)** | | | | | | | |
| Xc | 136.01 | 136.02 | 0.10 | 0.1716 | 0.54 | 0.76 | 0.9548 |
| A | 78.11 | 78.03 | 0.08 | 0.1982 | 0.63 | 0.89 | 0.6959 |
| Mxp | 38.23 | 38.19 | 0.04 | 0.2161 | 0.68 | 0.96 | 0.8573 |
| Is | 85.25 | 85.40 | 0.15 | 0.2544 | 0.80 | 1.13 | 0.5700 |
| **Vertical (mm)** | | | | | | | |
| Xc | 25.59 | 25.31 | 0.28 | 0.2760 | 0.87 | 1.23 | 0.3368 |
| A | 43.06 | 42.89 | 0.17 | 0.2319 | 0.73 | 1.03 | 0.4822 |
| Mxp | 41.01 | 40.82 | 0.19 | 0.1952 | 0.62 | 0.88 | 0.3558 |
| Is | 62.70 | 62.55 | 0.15 | 0.2841 | 0.90 | 1.27 | 0.6103 |
| **Angular (°)** | | | | | | | |
| Ppa | 2.94 | 3.01 | 0.07 | 0.1850 | 0.59 | 0.83 | 0.7140 |

†5% level of significance

## 3.2 The Whole Sample

The mean skeletal and dental changes for the whole sample are displayed in Table 3.2a, Figures 3.2a, 3.2b and 3.2c. Calculated correlation coefficients are displayed in Table 3.2b

### *3.2.1 Post-operative changes (T1-T2)*

The maxilla was advanced a mean 3.6 mm at point A (range 1.5 to 5.5 mm), 3.8 mm at point Mxp (Table 3.2a, Figures 3.2a, 3.2b). Point Is was displaced anteriorly to a lesser degree than points A and Mxp by a mean 2.1 mm (range 0.1 to 4.3 mm)

Point A was positioned inferiorly a mean 2.8 mm (range 2.0 to 5.2 mm). Point Mxp was positioned superiorly a mean 0.4 mm. In four patients however, the surgical movement at the posterior maxilla was downwards (range 0.3 to 0.7 mm). In the remaining six, the surgical movement of the posterior maxilla was superiorly directed (range 0.4 to 1.9 mm). Point Is was displaced downwards a mean 3.2 mm (range 2.1 to 5.7 mm).

The palatal plane was rotated clockwise during the surgical procedure, as indicated by a mean change of 4.6° in the palatal plane angle (range 3.1° to 6.9°).

### *3.2.2 Long-term changes (T3-T2)*

The mean horizontal stability of the maxilla was nearly 100%. A mean forward movement of 0.1 mm was registered at point A (Table 3.2a, Figures 3.2a, 3.2c). Three patients showed relapse in a posterior direction (range 0.2 to 2.3 mm), while the remaining seven showed movement in an anterior direction (range 0.5 to 0.9 mm). Horizontal changes at point Mxp closely followed those of point A. Point Is moved anteriorly a mean 0.8 mm. Two of the patients experienced a posterior movement at point Is of 0.4mm and 1.2 mm, while the remaining eight experienced an anterior displacement at this point (range 0.3 to 4.1 mm).

Point A relapsed superiorly a mean 0.9 mm. This represented a mean 32.1% relapse at the anterior maxilla. In five of the patients there was a minimal change that ranged from -0.1 to 0.2 mm. It can therefore be stated that they were stable vertically. The remaining five patients had relapsed superiorly with a range of 0.6mm to 2.4 mm.

There was a positive correlation (r= 0.7490) between the magnitude of inferior repositioning at point A immediately post-operatively, and the tendency for relapse at this point (Table 3.2b). As the absolute amount of inferior repositioning at point A increased, so did the tendency for relapse from T2-T3. A significant relationship between these two parameters was found (P= 0.000).

The posterior maxilla was fairly stable, having relapsed superiorly a mean 0.2 mm at point Mxp (range -1.1 to 0.8 mm).

Movement at point Is had averaged 1.7 mm superiorly. In one patient there was an inferior movement of 2.0 mm, while in the remaining nine patients point Is had moved superiorly with a range of 0.4 mm to 3.8 mm.

The palatal plane had relapsed a mean 1.6° in an anticlockwise direction (Table 3.2b). In two patients the magnitudes of change were minimal (-0.1° and 0.2°), while in the remaining eight there was an anticlockwise rotation in the range of 0.7° to 4.0°. There was a statistically significant correlation between the absolute amount of clockwise rotation of the palate at surgery, and the long-term relapse in an anticlockwise direction (r= 0.7408, P=0.0000).

The ratio of absolute amount of change at point A was a mean 1.4 at surgery, and 3.4 at the long-term (Table 3.2b). The two were however poorly correlated and the difference was not statistically significant (r= 0.3160, P= 0.2013).

**Table 3.2a** Mean changes of landmarks at surgery and long-term.

| Whole sample n= 10 | At surgery T1-T2 | | Long-term T2-T3 | |
|---|---|---|---|---|
| Landmark | Mean | SD | Mean | SD |
| | | Horizontal Changes (mm) | | |
| Point A | 3.6 | 1.2 | 0.1 | 1.0 |
| Point Mxp | 3.8 | 1.2 | 0.0 | 1.0 |
| Point Is | 2.1 | 1.5 | 0.8 | 1.4 |
| | | Vertical Changes (mm) | | |
| Point A | -2.8 | 1.0 | 0.9 | 1.0 |
| Point Mxp | 0.4 | 0.9 | -0.2 | 0.5 |
| Point Is | -3.2 | 0.9 | 1.7 | 1.8 |
| | | Angular Changes (°) | | |
| Ppa | 4.6 | 1.3 | -1.6 | 1.4 |

*Horizontal: -Ve = Backward; +Ve = Forward
*Vertical: -Ve = Down; +Ve = Up
*Angular: -Ve = Counter-clockwise; +Ve = Clockwise

**Table 3.2b** Calculated correlations between the various parameters, post-operatively and long-term, for the total sample. The mean values represent absolute magnitudes of change.

| | Independent variable Mean T1-T2 | Dependent variable Mean T2-T3 | r | P† |
|---|---|---|---|---|
| Horizontal (mm) | | | | |
| A | 3.6 | 0.7 | 0.1381 | 0.0020 |
| Mxp | 3.8 | 0.6 | -0.1742 | 0.0010 |
| Is | 2.1 | 1.1 | -0.2352 | 0.1708 |
| Vertical (mm) | | | | |
| A | 2.8 | 0.9 | 0.7490 | 0.0000 |
| Mxp | 0.8 | 0.5 | 0.6009 | 0.0343 |
| Is | 3.2 | 2.1 | 0.2027 | 0.2840 |
| Angular (°) | | | | |
| Ppa | 4.6 | 1.6 | 0.7408 | 0.0000 |
| Ratio | | | | |
| RA | 1.4 | 3.4 | 0.3160 | 0.2013 |

†5% level of significance

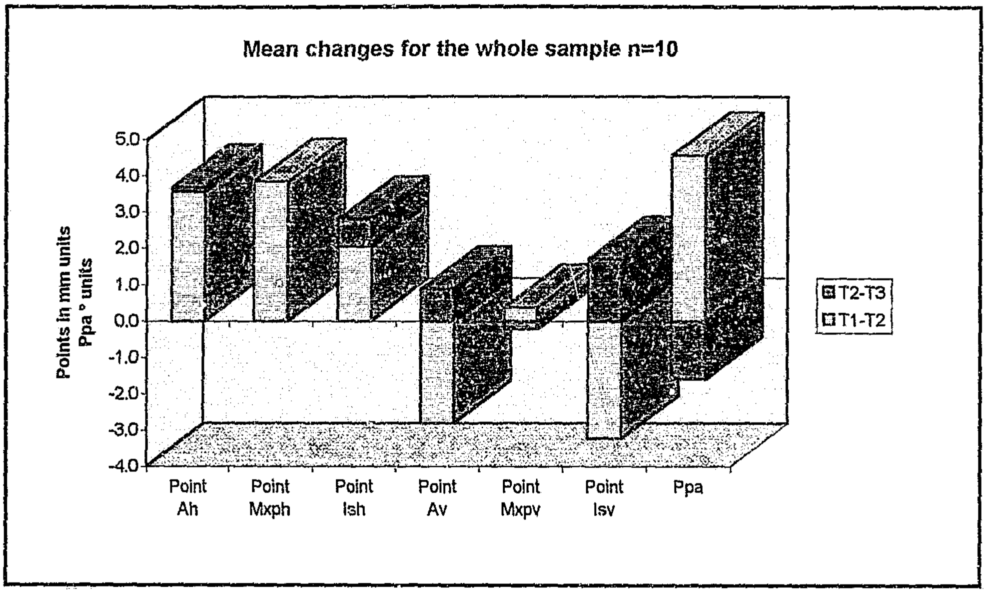


**Figure 3.2a** Mean changes of landmarks at surgery (T1-T2) and long-term (T2-T3).

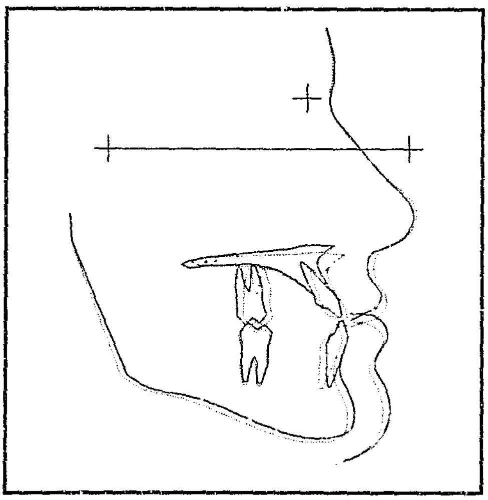

**Figure 3.2b** Superimposition of mean cephalograms at 1 week preoperatively (solid line) and 1 week post-operatively (dotted line).

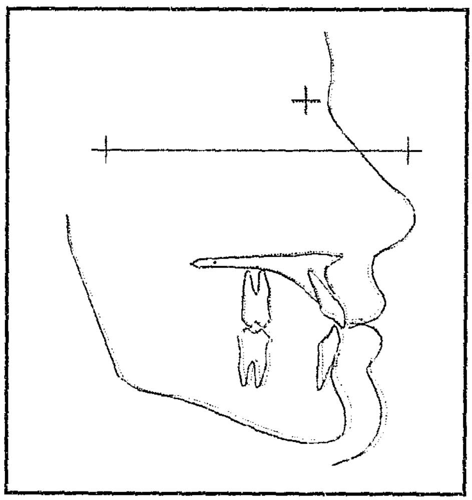

**Figure 3.2c** Superimposition of mean cephalograms at 1 week post-operatively (solid line) and at > than 6 months (dotted line).

## 3.3 Wire Fixation Vs. Rigid Fixation

The mean change in position of the different landmarks for two subgroups are compared in Table 3.3. Three patients underwent a single jaw operation and wire fixation while four patients underwent a single jaw operation and rigid fixation.

The maxilla was positioned forward on average at point A, nearly twice as much in the rigid fixation group as in the wire fixation group (4.5 mm vs. 2.3 mm). The mean horizontal long-term position of point A was more stable for the rigid fixation group (a forward 0.2 mm vs.0.9 mm). Horizontal changes at the posterior maxilla (point Mxp) were similar. Horizontal long-term changes at point Is were smaller in the rigid fixation group (a forward 0.5 mm vs. 1.7 mm).

The mean vertical stability at point A was not much different in the rigid fixation group compared to the wire fixation group (an upward 1.4 mm relapse vs. 1.0 mm). The mean long-term vertical change at point Mxp was also not much different for both groups (0.0 mm vs. a downward 0.3 mm). The mean vertical long-term change at point Is was smaller in the rigid fixation group (an upward 1.7 mm vs. 2.6 mm).

The palatal plane rotated in an anticlockwise direction in both groups. The magnitude of this mean change was not much different (-2.0° vs. -2.1°). The initial clockwise rotation at surgery was however slightly greater in the wire fixation group (5.4° vs. 4.3°).

No statistically significant difference was found between these two groups, in respect of the mean changes.

**Table 3.3** Mean changes of the landmarks. Single jaw surgery and wire fixation (n= 3) vs. single jaw surgery and rigid fixation (n= 4).

| Landmark | WIRE FIXATION At surgery T1-T2 | WIRE FIXATION Long-term T2-T3 | RIGID FIXATION At surgery T1-T2 | RIGID FIXATION Long-term T2-T3 |
|---|---|---|---|---|
| | Horizontal change (mm) | | Horizontal change (mm) | |
| Point A | 2.3 | 0.9 | 4.5 | 0.2 |
| Point Mxp | 2.6 | 0.9 | 4.7 | 0.0 |
| Point Is | 0.4 | 1.7 | 3.3 | 0.5 |
| | Vertical change (mm) | | Vertical change (mm) | |
| Point A | -3.7 | 1.0 | -2.7 | 1.4 |
| Point Mxp | 0.0 | -0.3 | 0.4 | 0.0 |
| Point Is | -3.7 | 2.6 | -3.0 | 1.7 |
| | Angular change (°) | | Angular change (°) | |
| Ppa | 5.4 | -2.1 | 4.3 | -2.0 |

*Horizontal: -Ve = Backward; +Ve = Forward
*Vertical: -Ve = Down; +Ve = Up
*Angular: -Ve = Counter-clockwise; +Ve = Clockwise

## 3.4 The Effect of a Concomitant Mandibular Osteotomy (BSSO)

The mean changes for the two subgroups, determined by the absence or presence of a mandibular operation, are displayed in Table 3.4. In both subgroups the mode of maxillary stabilisation was rigid fixation. Three patients underwent a double jaw operation. Four patients underwent a single jaw operation.

Posterior relapse at point A had averaged 0.8 mm in the double jaw group. The single jaw group experienced a mean 0.2 mm anterior relapse at point A. The mean horizontal change at point Is was slightly less in the double jaw group (an anterior 0.2 mm vs. 0.5 mm).

Point A was positioned inferiorly a mean 2.1 mm in the double jaw group, and 2.7 mm in the single jaw group. There was no mean long-term vertical relapse at point A in the double jaw group. The single jaw group experienced a mean superior relapse of 1.4 mm at this point. The mean vertical change at point Is was smaller in the double jaw group (an upward 0.9 mm vs. 1.7 mm).

The double jaw group experienced a mean anticlockwise long-term change of only 0.5° in the palatal plane. The group that did not have mandibular surgery, experienced a mean 2.0° anticlockwise relapse.

No statistical significance was found in respect of the mean changes, for these two subgroups.

**Table 3.4** Mean changes of the landmarks. Single jaw surgery and rigid fixation (n= 4) vs. double jaw surgery and rigid fixation (n= 3).

| Landmark | SINGLE JAW SURGERY AND RIF | | DOUBLE JAW SURGERY AND RIF | |
|---|---|---|---|---|
| | At surgery T1-T2 | Long-term T2-T3 | At surgery T1-T2 | Long-term T2-T3 |
| | Horizontal change (mm) | | Horizontal change(mm) | |
| Point A | 4.5 | 0.2 | 3.7 | -0.8 |
| Point Mxp | 4.7 | 0.0 | 3.9 | -0.9 |
| Point Is | 3.3 | 0.5 | 2.1 | 0.2 |
| | Vertical change (mm) | | Vertical change (mm) | |
| Point A | -2.7 | 1.4 | -2.1 | 0.0 |
| Point Mxp | 0.4 | 0.0 | 0.7 | -0.4 |
| Point Is | -3.0 | 1.7 | -3.0 | 0.9 |
| | Angular change (°) | | Angular change (°) | |
| Ppa | 4.3 | -2.0 | 4.1 | -0.5 |

*Horizontal: -Ve = Backward; +Ve = Forward
*Vertical: -Ve = Down; +Ve = Up
*Angular: -Ve = Counter-clockwise; +Ve = Clockwise

## 4.0 DISCUSSION

An important aspect of any research utilising cephalometrics is to report on the amount of error. An attempt was made to reduce the error by utilising a best-fit template for the maxilla,[25] by digitising each point four times, and by repeating the technique one month later.[26]

The 95% confidence limit of measurements reveals a magnitude of potential error that must be considered (Table 3.1). Point A was used as an indicator of skeletal stability and point Is was used as an indicator of dental stability. The 95% confidence limit for point A was 0.63 mm for the horizontal and 0.73 mm for the vertical dimension. Reciprocal values for point Is were 0.80 mm and 0.90 mm respectively. When measuring skeletal changes across two cephalograms at point A, the amount of potential error is doubled to 1.26 mm horizontally and 1.46 mm vertically. These findings compare well to those reported and considered by others.[12, 15, 27]

The superimposition technique in this study included anatomically stable cranial structures to determine a reference plane. Concerning registration point Xc, the 95% confidence limit was 0.76mm horizontally and 1.23 mm vertically. When two consecutive superimpositions were performed for each case, the potential error could have therefore been double these figures.

The compounding effect of the potential error in determining a reference plane, plus the potential error of locating each point, makes the interpretation of results for any cephalometric study complex. For each case in the present study the location of landmarks was performed in three cephalograms, and involved two superimpositions. However, having averaged replicate values, a single measurement 95% confidence limit was reduced by a factor of $\sqrt{2}$.[27] The reader is therefore encouraged to regard the findings of this, and of any other cephalometric study, with consideration to the magnitude of potential error.

The findings reveal a degree of skeletal stability for the Le Fort I downsliding osteotomy that is similar in trend to that of other procedures, involving an inferior and anterior maxillary repositioning. The mean 32.1% superior relapse at the anterior maxilla compares favourably with that reported by others,[3, 11] but is greater than the 14.8% noted in the previous report.[4] It is reasonable to assume that an osteotomy design that creates good bony interfacing between the segments, promotes a better dissipation of detrimental occlusal forces.[3,5] By "downsliding" the segments along an angulated osteotomy cut good contact is achieved. It is important to note however that the mean relapse reflects on a wide individual variation. In five of the patients there was a nearly 100% stability at the anterior maxilla, while in the remaining five patients superior relapse occurred with a range of 18.1% to 71.2%. The anterior maxilla was stable on average in the horizontal dimension. Three of the patients however experienced a posterior relapse and seven of the patients demonstrated an anterior movement.

When the maxilla is downgrafted the same amount anteriorly as posteriorly in non open-bite cases, and more so in open bite cases, an anterior open bite will result. The surgical design in all cases should therefore be such that the vertical increase of the maxilla is less posteriorly than anteriorly. The maxilla is essentially rotated as it is advanced (Figure 2.2). An examination of the palatal plane angle confirms that such a rotation was indeed performed at surgery (Table 3.2a). The variable rate of relapse cannot be explained by changes in length of the mandibular elevators. The mandible appears to have rotated slightly clockwise at surgery, if one examines the mean cephalometric tracings (Figure 3.2b). The posterior aspect of the maxilla was however not repositioned inferiorly at surgery. It is also unlikely that the mean amount of inferior repositioning in this study, exceeded the preoperative freeway space.

A comparison regarding the mode of fixation reveals similar trends and no significant differences. A slightly better resistance to the horizontal vector of relapse was noted for the group that underwent rigid internal fixation (Table 3.3). The rigid fixation group was positioned inferiorly slightly more than the wire fixation group. The mean amount of superior relapse was nevertheless alike. The mean change at the posterior maxilla was minimal. Rigid fixation was shown to be significantly better than wire fixation for large inferior movements, with increased lengthening of the muscles, and a large interpositional bone graft.[16] The amount of inferior maxillary movement with the downsliding technique is however relatively small and does not necessarily involve a large amount of lengthening of the musculature, bony contact is maximised, and there is little need for grafting. It is sensible to assume that skeletal stability may not be significantly enhanced by rigid internal fixation with this technique.

The group of patients that underwent a double jaw procedure with rigid internal fixation, had no vertical relapse at the anterior maxilla (Table 3.4). It is possible that rigid fixation improves the vertical maxillary outcome in double jaw cases, as suggested by de Mol van Otterloo et al.[9] The group of patients that underwent a single jaw procedure with rigid internal fixation experienced a mean 1.4 mm superior relapse at the anterior maxilla, in comparison. There was no evidence of a lengthening of the muscles from the changes observed at the posterior maxilla in either group. Perhaps an osteotomy design that causes a lengthening of the elevator muscles would benefit from a bimaxillary operation for stability.[12, 15, 20,]

The study reveals that a greater amount of inferior repositioning at the anterior maxilla is likely to be followed by a greater amount of superior relapse. The same finding was reported by some researchers,[8, 12] while others[3, 6, 11, 18,] found differently. It is likely that a greater inferior repositioning may encroach further on the freeway space, and disturb the soft tissues and musculature to a greater extent. The amounts of inferior repositioning observed in this study were however relatively small in comparison to those reported by others.

In the previous report[4] it was recommended that the angulated osteotomy cut is performed with a 2:1 ratio of advancement to inferior repositioning. The findings of this study indicate that a specific ratio of surgical change at the anterior maxilla does not yield a specific ratio of relapse tendency. The desired amount of tooth exposure and improvement in soft tissue appearance, should therefore dictate the angulation of the anterior osteotomy cut. The posterior osteotomy cut is angulated to a lesser degree than the anterior cut so that the maxilla follows the occlusal plane of the mandible as it rotates clockwise (Figure 2.2).

The upper incisor tip had moved on average to a more superior and anterior position at the long-term as compared with its post-operative position. Similar changes were found by Baker and Stoelinga[8] and by Proffit et al.[15] for their maxilla-down group. This study did not reveal statistically significant correlations between the long-term change of upper incisor position and any of the other parameters examined. Perhaps a follow-up study with a larger sample size will reveal otherwise. The long-term stability of the upper incisors is probably dependent on a number of factors such as: the long-term stability of the maxilla, the integrity and amount of periodontal support of the incisor roots, the long-term stability of the mandible, the stability of the post-operative posterior occlusion and mandibular incisor position, and the balance of forces applied by newly established soft and hard tissue adaptations, following the orthodontic-surgical intervention.

The amount of upper lip lengthening and upper incisor exposure is important in assessing the success of this type of procedure.[3, 11] Bell and Scheideman[11] suggested that a vertical relapse factor of 2 mm should be considered when performing a maxillary downgrafting. They proposed that this value can be used when planning the desired long-term amount of upper incisor exposure. The mean change in this study at point Is was 1.7 mm in a superior direction (Table 3.2a). The 2 mm guideline may therefore be useful for the downsliding technique as well. Due consideration must however be given to the technical effect of an additional amount of maxillary downgrafting anteriorly. Such a change results in a steeper anterior osteotomy plane and imposes a limitation on the amount of maxillary advancement possible.

An important consideration is that soft tissue behaviour could be a major contributor to the variable skeletal stability observed.[19] It is known that presurgical orthodontic patients demonstrate a reduction in masticatory efficiency and maximum bite forces.[23, 32-34] The reason for this is unknown.[23] Some believe that it is the result of the pain and inconvenience rendered by the orthodontic appliances.[34] The orthodontic tooth movements prior to surgery may sometimes cause a worsening of the occlusion, and may thus explain the functional change of the musculature.[35] It is thought that individuals with a vertical maxillary deficiency exhibit greater masticatory forces than other individuals.[2, 22] Perhaps the masticatory forces become reduced somewhat preoperatively but are strong enough to procure long-term skeletal changes. Although it was presumed that no lengthening of mandibular adductors occurred in cases under this study, there were no means to examine what functional changes did occ[illegible] There is an ever increasing need to evaluate functional changes following orthognathic procedures. Current methods of study are however not adequate, and the number of studies in this field is limited.

## 4.1 Conclusions

The utilisation of a cephalometric analysis to assess treatment changes is accompanied by methodological error that may be reduced to some extent. The skeletal stability of the Le Fort I downsliding osteotomy is variable. Single jaw surgery and rigid internal fixation shows no difference in stability than with wire osteosynthesis. Bimaxillary surgery with rigid internal fixation shows no difference in stability compared to isolated maxillary surgery and rigid internal fixation. Greater inferior surgical movement at the anterior maxilla is likely to be accompanied by a greater amount of superior relapse. No specific ratio of advancement to inferior repositioning at the anterior maxilla yields a specific ratio of relapse. A 2 mm relapse value may be useful in planing the desired vertical amount of upper incisor exposure, but this may limit the amount of maxillary advancement possible with the downsliding technique. The measurement of muscle behaviour may reveal important rationale for the instability that accompanies orthognathic procedures.

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