UNIVERSITY OF ALBERTA

A COMPARISON OF RELAPSE OF SURGICALLY DOWNGRAFTING THE MAXILLA FOLLOWING RIGID INTERNAL AND WIRE FIXATION

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled

"A COMPARISON OF RELAPSE OF SURGICALLY DOWNGRAFTING THE MAXILLA FOLLOWING RIGID INTERNAL AND WIRE FIXATION"

submitted by Gerald Ernest Philippson in partial fulfillment of the requirements for the degree of Master of Science.

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DEDICATION

This work is dedicated to my wife Ana and my children Jacinta, Cassia and Lucas. For without their continuous support, encouragement and love, this project, and my specialty training would have been impossible.

ABSTRACT

Stability following downgrafting of the maxilla has not proven satisfactory following either rigid internal fixation or wire fixation. Due to the infrequency of the procedure, past studies have included cases that were completed by different surgeons with different surgical methods. This retrospective study analyses 11 cases treated by the same oral surgeon using rigid internal fixation and compares them to 11 cases treated by a different oral surgeon completed by wire fixation. Follow-up period for the experimental group was 16 $\pm$ 11 months and the comparison group had a follow-up of 20 $\pm$ 12 months. Anterior vertical relapse in the experimental group was 9.7 $\pm$ 10.1% while the comparison group had a relapse of 46.9 $\pm$ 35%. Relapse in the experimental group is significantly ($p<0.5$) less than the comparison group. The results of this study show downgrafting of the maxilla using autogenous bone harvested from the iliac crest and rigid internal fixation to be a predictable and stable procedure.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

The short face syndrome must be accepted as a potential occurrence in every orthodontic practice. The treatment of the problem can be as varied as the cause. Turley[1] discussed the different possibilities that can cause the short face syndrome which include; a deficient maxilla, a deficient mandible, a deficient upper third of the face, as well as combinations of the above.

The lower two thirds can produce four subgroups of problems according to Freihofer[2] which include, insufficient skeletal height of the anterior part of the mandible, a short mandible with a deep vertical overbite, a deficient maxilla including retrognathia and vertical insufficiency, and finally, the deficient face where the nose and infraorbital rims are depressed.

To correct the insufficiency, the surgical and orthodontic management should be directed toward the problem. If the major problem is in the mandible, then the surgical procedure should be alteration of the mandible. Likewise, if the problem is in the maxilla, then the surgical approach should be to improve the position of the maxilla.

VERTICAL MAXILLARY DEFICIENCY

The condition known as vertical maxillary deficiency (VMD) is the third subgroup mentioned by Freihofer[2]. Wolford and Hilliard[3] suggest that these people appear overclosed, usually with the maxillary central incisor above the level of the upper lip. Both the labiomental and nasolabial angles are reduced. Bell and Scheideman[4] observed that in cases of VMD, the physiologic rest position of the mandible provides an extreme freeway space.

Wessberg and Epker[5] suggest that people with true vertical maxillary hypoplasia also generally exhibit an overclosed appearance resulting in relative mandibular prognathism, excessive lip competence, accentuated subnasal and labiomental grooves, and acute nasolabial angles. They also agree with previous reports of an increased interocclusal space at the physiologic rest position of the mandible.

SURGICAL MANAGEMENT

The objectives of the orthodontic and surgical correction of VMD is improvement of facial aesthetics and masticatory function. The treatment of choice according to Freihofer[2] is to employ a surgical procedure known as the Le Fort I osteotomy where the maxilla is cut inferior to the zygomatic process and anterior to the lateral aspect of the nasal margin. An osteotome is used to fracture the pyramidal processes of the sphenoid bone and also to separate the nasal septum and vomer from the hard palate. Due to the nature of the surgery, the blood supply is lost from the nasopaltine artery, however, a careful surgical approach will maintain sufficient arterial supply from the greater palatine arteries.

Moloney and Worthington[6] found that the Le Fort I osteotomy is often historically attributed to the surgery performed in 1927 by Martin Wassmund to correct an anterior open bite malocclusion. However, the first surgical procedure using the Le Fort approach can be traced to 1867 where the osteotomy was performed to surgically approach a nasopharyngeal tumour[6]. Rosen[7] suggested that the surgery has an acceptably low rate of morbidity. Perko[8] agreed with the low level of complications showing that the Le Fort osteotomy of the maxilla has been cited in the literature since 1942. In his study, Perko[8] showed that the complication rate following Le Fort I and III procedures was no greater than that following fractures to the middle third of the face.

One procedure to increase the vertical height of the maxilla is described by Piecuch, et al[9] where they report on the case of a woman with myofascial pain whose treatment included splint therapy to restore the physiologic rest position prior to surgical movement of the maxilla. The treatment included fixation of the mandible with an external frame to the treated position and downgrafting the maxilla to this corrected position. Corticocancellous bone was interposed in the space created by the osteotomy, but the bones were not wired because of the rigidity afforded by the external frame. No follow-up report on relapse using this technique was made.

Another method to increase the vertical height is to downfracture the maxilla and support the mobile segment with iliac crestal bone wired into place. Bell and Scheideman[4] report an average relapse of 31.4% with one case relapsing 100% while Freihofer[2] and Hedemark and Freihofer[10] report 50% relapse. Wolford and Hilliard[3] report 20 to 70% relapse that was thought to be due to the "pumping" action of the mandible against the maxilla. Garrison et al[12] also found relapse ranging from 0 to 100%.

Wessberg and Epker[5] suggested that Starling's law, which states that an overstretched muscle can have an increased contractile strength, has an effect on the relapse of the downgraft. Turvey[11] agreed and suggested that relapse is probably due to overstretching the elevator muscles following surgical downgraft.

Wolford and Hilliard[3] report on the use of threaded Steinmann pins that are screwed into the zygomatic process of the maxilla and attached to a splint that supports the occlusal function of the mandible during the time of healing. Although they reported no measures of relapse, Wolford and Hilliard[3] suggested that it appeared to be extremely effective in providing appropriate vertical stability.

Quejada[13] looked at the stability of wire fixation in ten patients and found that even with a modified procedure, the downgrafted segment proved quite unstable. If the bony cuts are placed as inferior as possible, and the anterior maxillary face height is increased while minimizing increases in posterior maxillary height, the mean relapse was approximately 2 mm. One half of the relapse occurred during the period of fixation of the jaws and the other half took place up to 6 months after surgery.

RIGID INTERNAL FIXATION

In order to reduce the potential for relapse, as well as improve the postoperative course, bone plates were introduced to orthognathic surgery. Drommer and Luhr[14] report on the use of mini plates in Le Fort I osteotomies in cleft palate cases in 1981 and suggested that the applications would improve surgery in the maxilla and mandible. Steinhauser[15] reported on their use and suggested there was faster bone healing, and therefore less relapse. Although no statistical comparisons were made, he suggested that use of bone screws and plates was a major improvement in the correction of deformities in the maxillofacial region.

The Le Fort I osteotomy stabilized by bone plates as described by Kraut[16] involves downfracturing the maxilla and securing the mobile segment with four plates composed of either titanium or stainless steel. The plates are attached with 7 mm screws that engage dense cortical bone at each piriform margin and zygomatic buttress. These areas are chosen since the piriform aperture and zygomatic buttress provide the thickest bone for penetration of the screws[17]. The patients are normally completed with maxillomandibular fixation (MMF) for a period up to two days when the wires are cut and the patient released from hospital.

Buckley et al[18] compared advantages of the rigid internal fixation with wire fixation. They found a significantly greater weight loss in the wire fixation group where there was MMF postoperatively. Also, the rigid fixation group had greater temporomandibular joint mobility six months postoperatively than the wire fixated group. They also found a higher incidence of postoperative infection following plating than with wire fixation. The infections were easily handled with antibiotics, incision and drainage. Several patients had the plates and screws removed under local anaesthetic. They concluded that the benefits outweighed the costs of rigid fixation.

Rosen[17] also discussed the disadvantages and included the cost of the plates, increased operating time, and the difficulty to orthodontically correct the improper placement of the segments. He concluded that while rigid fixation is desirable in terms of elimination of postoperative immobilization of the mandible, it can also be a liability if the procedure is not performed with close attention to detail and a commitment to repeat the steps of plate fixation if skeletal position is incorrect. The correct position of the segments can be assured by meticulous preoperative splint fabrication, and intraoperative verification of the fit of surgical splints. As well, the increase in operative time should not be a consideration if the procedure offers superior postoperative results.

Ellis et al[19] described an experimental study of downgrafting the maxillae of adult *Macaca mulatta* monkeys and comparing the stability with rigid internal fixation (5 animals), wire fixation (4), myotomies of the masseter and temporalis (5) and a group treated with a bite opening appliance prior to downgrafting (4). The follow-up period was twelve weeks in duration.

They found that all groups relapsed. The least amount of relapse occurred in the group with rigid internal fixation followed by the myotomy group and then the group pretreated with a bite opening device. The relapse following bone grafting and wire fixation had the most amount of relapse with only 15% retention following the twelve week period of study. Animals in each group developed infections requiring drainage and produced sequestration of bone, but the authors deny any effect on the stability. Questions can be raised as to the effect of the infections as well as the small sample size.

Other potential methods of supporting the segments is to interpose porous hydroxyapatite. Wardrop and Wolford[20] looked at the stability of downgrafting, and advancing the maxilla with porous hydroxyapatite interpositional implants as a bone graft substitute. Their results show less than 1 mm (approximately 9%) relapse in any dimensional movement. No complications related to the implants were noted. Their terms of reference for measuring stability were the incisor edges and the first molars, both of which can be significantly influenced by orthodontic movements.

Rosen and Ackerman[21] also looked at the stability with porous hydroxyapatite and found that the mean vertical relapse was 4.5% with 3 of 10 patients exhibiting increases in vertical dimension, rather than relapse. In their report, three of seventy-five cases (only ten of which were inferior displacement of the maxilla) developed complications with the implants with one dislodging, one being palpable by the patient and another involving an infection. In the case where the plate was dislodged, it was removed with a transnasal surgical approach and the others were surgically debrided and contoured.

Persson et al[22] looked at stability of downgrafting using rigid fixation, without interpositional bone. Their patients were placed in MMF for an unspecified time and radiographs taken preoperatively, postoperatively, at the release of MMF, and six months postoperatively. They found relapse of 20% (1.5 mm) at the time of the removal of MMF which did not diminish at the six month radiograph. They concluded that the procedure of rigid internal fixation is at least as stable as that obtained with other techniques. However, 20% relapse is superior to any other reported techniques using plates and autogenous bone as the support medium.

Baker et al[23] looked at long-term stability of inferior repositioning of the maxilla using mini-plate fixation. Their nineteen cases had follow-up periods of up to 58 months. The surgical group came from the clinic at the Department of Oral and Maxillofacial Surgery, Rijnstate Hospital, Arnhem, The Netherlands and the procedures were completed by different surgical residents over a four year period. In their analysis of the data, they found difficulty in locating landmarks such as the posterior nasal spine, anterior nasal spine (ANS) and incisor tip but still relied upon the incisor to locate the body of the maxilla for analysis. Unfortunately, the incisor is not a stable unit of the maxilla and can move in relation to the body. Thus movement of the incisor can influence the interpreted relapse of the maxilla.

In spite of the problems in locating the maxilla, and possibly due to them, Baker et al[23] report significant relapse in their study. They separated the patients into 3 groups. Group 1 had no relapse of the inferior movement with movement from 1.5 to 9.5 mm. Group 2 had 12 to 25% vertical relapse and the patients in this group had inferior repositioning of 7 to 10 mm. Group 3 experienced 30 to 50% relapse with initial inferior movement of 1.5 to 12 mm. Five patients did not receive bone grafts and 1 of these experienced relapse of 50%. Even though inferior repositioning in this case was 5 mm no bone graft was placed. From this they concluded that bone grafts are probably necessary for any gap larger than 3 mm. From their study, they concluded that relapse following inferior movement of the maxilla is unpredictable even with the use of miniplates.

CEPHALOMETRIC ANALYSIS

The tissues of interest are the maxilla and its downfractured structures. Determining landmarks for the maxilla may be difficult as the ANS is often removed during Le Fort I procedures, and is difficult to accurately locate on cephalometric films. A point, as shown by Baumrind and

Frantz[24], is unreliable, especially in the vertical dimension which would introduce error in the measure of vertical stability.

Houston et al[25] described a method of recording change in the maxillary position following orthognathic surgery. They traced, from the presurgical cephalogram, the sella turcica and the anterior cranial base. The maxillary structures to be traced were decided upon after inspection of the three radiographs from each individual case. They did not recommend teeth or dental restorations for registration as they can move post-surgically.

The cephalometric analyses in both the Persson et al[22] and the Baker et al[23] articles use the incisor tip to locate the maxilla for digitization. By using an unstable structure such as the incisor tip to locate the maxilla, the subsequent measures at ANS, PNS, and A Point can be in error.

RESEARCH QUESTION

The studies undertaken to analyse relapse with rigid internal fixation have been retrospective in nature. Inclusion criteria for cases has been liberal by including cases with multifactorial variables in a relatively small sample size, completed by different surgeons with different techniques, as well as different types of fixation methods.

In order to improve the study methodology, a randomized clinical trial should be considered. Unfortunately, due to the limited number of cases of maxillary downgrafts performed, it would be difficult to arrive at sufficient numbers in a conceivable time frame. Therefore, a study that is retrospective in nature is inevitable.

To have some consistency in the surgical procedure, it would be preferable to have one surgeon complete all the cases. In this manner a consistent surgical technique is more likely. It would be unusual for one surgeon to have completed a large number of cases in both wire fixation and rigid internal fixation. Therefore, as a compromise, one surgeon at the most should have completed all the cases in the rigid internal fixation group, while another surgeon completed the cases in the wire fixation group.

One other criteria should be that the cases in each group all be treated the same. For the rigid fixation group, all cases should be plated in a similar manner. They should all have cortical bone grafted in the osteotomy gap and there should be minimal MMF (2 days or less).

For the wire fixation group all cases should be treated in a similar manner. No method to support the mobilized segment, other than bone, should be employed. This would preclude the use of Steinmann pins, external frames or plates. As well, the patients should be maintained in MMF during the six week healing phase.

It is assumed that downgrafting with rigid internal fixation, using a standardized method of surgery, and bone placed within the osteotomized site, will be more stable with less relapse than downgrafting using bone as the sole supporting medium.

The purpose of this study is to compare the postsurgical stability of downgrafting the maxilla using rigid internal fixation, without a significant period of MMF, with that using wire fixation and six weeks of MMF.

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CHAPTER TWO - RESEARCH PAPER

INTRODUCTION

Vertical maxillary deficiency is a difficult orthodontic and surgical problem. Inferior repositioning of the maxilla is the logical correction of the deformity and has been discussed in the literature since 1977[1]. Unfortunately, relapse following the procedure has been reported from 0 to 100%[1-7]. Procedures to reposition the maxilla have included the use of rigid internal fixation or wire fixation, where the mobile osteotomized segment was supported by bone.

Rigid internal fixation, using mini-plates, has been used in orthognathic surgery since 1981[8]. Stability of downgrafting the maxilla using rigid internal fixation, as reported in the literature, has not been shown to be superior to wire fixation. Persson et al[9] studied stability of 18 cases of inferior repositioning and found a frontal relapse of 20% with a range from 0 to 100%. Their technique varied where they used either 2 or 4 mini-plates, an unspecified period of maxillomandibular fixation (MMF), and either 1 or 2 screws in the mobile segment. They concluded that rigid internal fixation was more advantageous than wire fixation.

Baker et al[10] also looked at inferior repositioning. To show the relative rarity of the procedure, of 191 Le Fort I osteotomies completed over a 4 year period, only 19 underwent downgrafting. Their study came from records of the surgical residency programme in Arnem, The Netherlands. As such, some surgeries were completed by different residents and the technique also varied between patients in regard to bone placed between the ostectomized segments. Five patients did not receive a bone graft and one of those patients had at least 5 mm of inferior movement. In spite of the mini-plates, and in contrast to Persson et al[9], they reported the procedure was as unpredictable as wire fixation. They concluded that with bone properly grafted to close the gaps there is a more acceptable result, but they did not have sufficient numbers to confirm this assumption.

The question remains whether a consistent technique with bone grafted in the opening will improve stability of maxillary downgrafting. Presumably, one surgeon performing all surgeries would maintain a consistent technique.

This retrospective study compares stability of downgrafting the maxilla, using rigid internal fixation, with bone grafted into the osteotomized site, to downgrafting using wire fixation and bone as the only supporting medium.

MATERIALS AND METHODS

Due to the limited number of downgrafting procedures completed in orthognathic practice it is difficult to find a surgeon who has completed a large number of cases in both wire fixation and a consistent method of rigid fixation. The experimental group in this study was selected from the files of Dr. W. R. McDonald in private practice in Vancouver, British Columbia, Canada. All cases of maxillary downgrafting performed in the practice were examined. The comparison group was chosen from the records of Dr. W. R. Proffit at Chapel Hill, North Carolina, USA. All cases of downgrafting included in the database were examined.

For a case to be included in this study, it must have been completed by one surgeon, there had to be radiographs of the preoperative condition (T1), immediately postoperative (T2, within 2 days of surgery), at least 6 months follow-up (T3), and each radiograph had to superimpose without enlargement differences between films. Each case also needed solid anterior and posterior occlusion without missing teeth. The experimental group needed to exhibit a consistent surgical technique with 4 mini plates and cortical bone interposed in the osteotomy site. The comparison group had to have the downgrafted mobile segment wired and supported only by bone.

Each radiograph was traced while being blinded to individual patients and whether it was T2 or T3. Prior to tracing, the preoperative films were separated from the postoperative cephalograms and a code was designated for each case. The postoperative radiographs were given the same code but they were also numbered to enable identification and dating following tracing and digitizing. To reduce potential for bias, the radiographs were randomized prior to numbering.

Each case in the experimental group had Le Fort I osteotomy to downfracture the maxilla. Rigid fixation in this study was employed using 4 mini-plates in a similar manner as described by Kraut[11]. Cortical bone was harvested from the medial aspect of the anterior iliac crest and placed in the osteotomized space following plating. Two cleft cases underwent the same procedure but had corticocancellous bone grafted to cleft sites at time of the downgraft.

Each suitable case in the comparison group was downgrafted with a LeFort I osteotomy using cortical bone from the iliac crest as the supporting medium. The graft was wired to both the mobile and nonmobile osteotomized segments. Each case was then wired in MMF for a period of at least 6 weeks.

Identification landmarks are difficult to locate on the maxilla. Traditional analysis uses A point, anterior nasal spine (ANS), posterior nasal spine (PNS), incisor tip and possibly the first molar. A point is not stable, especially in the vertical dimension[12]. Thus relying on A point for superimposition would introduce error in a measure of vertical stability. ANS and PNS are difficult to visualize on radiographs, and therefore, would also introduce error.

During LeFort I surgery, ANS is often obliterated and cannot be considered a reliable landmark.

Digitizing the position of the maxilla was carried out according to the procedure described by Houston et al[13] using a sonic digitizer (Science Accessories Corporation, Graf/Pen GP6-3D). This procedure relies more on bony structures within the body of the maxilla such as the smooth cortical bone or consistent trabeculae rather than other unstable landmarks or teeth, which can, and do move postoperatively. Each tracing was digitized 4 times, in random order, and the resultant measurements were averaged.

Comparisons were made on baseline factors, age and sex, by a t-test and Fisher exact test. Within group comparisons across time were by paired t-test. Comparisons between groups on relapse were made by the analysis of covariance using the baseline measurement as a covariate. Associations were determined by Pearson correlations. All tests were at the 0.05 probability level.

The groups were separated into subgroups and analysed for differences due to different types of surgery performed (one piece vs split maxillae, surgery on the maxilla only vs maxilla and mandibular surgery), along with comparisons between age groups (>20 years vs $\leq$ 20 years). The experimental and comparison groups were also compared for percent relapse of the surgical movement.

RESULTS

The patient data is summarized in Table 1. Eleven cases met the selection criteria for the experimental group (9 cases had surgery in the maxilla only; 4 were downgrafted in one piece, 3 were split, 1 case had a unilateral cleft of the right and 1 case had a bilateral cleft). Two cases were downgrafted along with bilateral sagittal split osteotomies (using rigid fixation) of the mandible. In both cases the maxilla was split. MMF was employed for a maximum of 2 days in each case. Age was 25.2 ± 10.4 years with length of follow-up averaging 16 ± 11 months with a maximum of 38 months.

TABLE 1. DEMOGRAPHICS AND PROCEDURES IN EXPERIMENTAL AND COMPARISON GROUPS

	Experimental	Comparison
Age[1]	25.2 ± 10.4 years (14-54)	22.8 ± 12.5 years (14-42)
Sex (M/F)	5 / 6	5 / 6
Follow-up[1]	16 ± 11 months (6-38)	20 ± 12 months (6-39)
Procedures		
1. 1 piece maxillae without mandibular BSSO[2]	4	2
2. Split maxillae without mandibular BSSO[2]	3	4
3. 1 piece maxillae with mandibular BSSO[2]	0	4
4. Split maxillae with mandibular BSSO[2]	2	1
5. Cleft palate without mandibular BSSO[2]	2	0

1 Mean, standard deviation and range
2 Bilateral Sagittal Split Osteotomy

For the comparison group, eleven cases met the selection criteria. Six cases were completed with maxillary surgery only and 4 of those had split maxillae. The 5 remaining cases included bilateral sagittal split osteotomies in the mandible of which 4 maxillae were downgrafted in one piece. Age was 22.8 $\pm$ 12.5 years and follow-up averaged 20 $\pm$ 12 months with a maximum of 39 months.

Both groups had 6 females and 5 males. There were twice as many cases in the experimental group completed with one piece maxillae without mandibular surgery than the comparison group, however, the comparison group outnumbered the experimental group 4:3 when the maxilla was downgrafted and split without mandibular surgery. The comparison group (4) outnumbered the experimental group (0) with one piece maxillae downgrafted with mandibular surgery. Where the maxilla was split inclusive with mandibular surgery, the experimental group had 2 cases and the comparison group 1. Two cleft cases were included in the experimental group whereas the comparison group had none.

Measurements of anterior relapse for the experimental and comparison groups are shown in Table 2. The anterior inferior movement for the experimental group was 6.8 $\pm$ 2.7 mm with a relapse of 0.7 $\pm$ 0.6 mm. The experimental group had 7 cases with less than 10% relapse and the average relapse was 9.7 $\pm$ 10.1%, with a range of 0% to 34.3%.

Two of 11 cases in the comparison group had increased inferior movement (negative anterior relapse) with the other 9 having more than 40% relapse. The anterior inferior movement was 4.5 ± 3.6 mm with an average relapse of 2.4 ± 2.4 mm. This translated into percent relapse of 46.9 ± 35.0% with a range from -25.0% to 93.3%.

TABLE 2. ANTERIOR INFERIOR MOVEMENT AND RELAPSE IN COMPARISON AND EXPERIMENTAL GROUPS[1]

Experimental				Comparison			
Patient	Anterior Inferior Movement mm T2 -T1	Anterior Relapse T2 - T3 mm	Anterior Relapse T2 - T3 %	Patient	Anterior Inferior Movement mm T2 -T1	Anterior Relapse T2 - T3 mm	Anterior Relapse T2 - T3 %
RL	1.6	0	0	JM	0.8	-0.2	-25.0
DD	4.5	0.4	8.9	GL	2.1	1.0	47.6
HV[2]	5.1	0.9	17.6	LB	2.1	1.3	61.9
AH	6.1	0.7	11.5	TP	2.7	0.9	33.3
AG	6.3	0.1	1.6	MH	3.0	2.8	93.3
MD[3]	6.7	2.3	34.3	TD	3.2	1.9	59.4
AW	7.8	0.4	5.1	EW	3.3	2.8	84.5
CB	7.9	1.2	15.2	WM	3.4	-0.1	-2.9
BF	8.7	0.6	6.9	TB	6.2	3.5	56.5
SD	8.7	0.2	2.3	MW	9.2	3.9	42.4
SC	11.8	0.4	3.4	EL	13.0	8.5	65.4
Average Movement	6.8 ± 2.7	0.7 ± 0.6	9.7 ± 10.1	Average Movement	4.5 ± 3.6	2.4 ± 2.4	46.9 ± 35.0
Average Movement Without Cleft Cases	6.9 ± 1.9	0.4 ± 0.4	6.1 ± 5.0	N/A	N/A	N/A	N/A

1 Figures rounded to the nearest decimal
2 Unilateral cleft of the right alveolus and palate
3 Bilateral cleft of the alveolus and palate

A significant difference ($p<0.05$) was found in anterior inferior movement within the experimental group from T1 to T2 and T1 to T3. There was no significant difference in the changes from T2 to T3. When analysing changes in the comparison group, there was no significant change between any of the time periods.

A significant difference ($p<0.05$) in the percent anterior relapse between the two groups was found. The relapse in the comparison group was much greater and more variable than the experimental group.

Omitting the 2 cleft cases from the analysis shows a reduced variability in terms of relapse in the experimental group. The average inferior movement without the clefts is 6.9 ± 1.9 mm, with relapse of 0.4 ± 0.4 mm and a percent relapse of 6.1 ± 5.0%.

Table 3 shows posterior inferior movement of the experimental and comparison groups. As this study is concerned with relapse following inferior movement, any case that had initial superior movement in the posterior aspect of the maxilla was not included for analysis.

There was greater variability of relapse in the posterior than anterior inferior movement for both groups. Average posterior inferior movement for the experimental group was 2.8 ± 2.0 mm with a relapse of 0.6 ± 0.4 mm. Percent relapse was 31.9 ± 29.2%. However, the comparison group is much more variable than the experimental group. The average posterior inferior movement was 2.8 ± 3.0 mm with relapse of 0.5 ± 1.3 and a percent relapse of 0 ± 95.7%.

TABLE 3. POSTERIOR INFERIOR MOVEMENT AND RELAPSE IN COMPARISON AND EXPERIMENTAL GROUPS[1]

Experimental				Comparison			
Patient	Posterior Inferior Movement mm T2 - T1	Posterior Relapse T2 - T3		Patient	Posterior Inferior Movement mm T2 - T1	Posterior Relapse T2 - T3	
		mm	%			mm	%
MD[2]	0.8	0.1	12.5	EW	0.6	-0.3	-50.0
BF	1.3	1.5	115.4	MH	0.8	1.1	137.5
SD	2.0	0.3	15.0	JM	0.9	-1.7	-188.9
DD	2.1	0.8	38.1	TD	1.9	-0.6	-31.6
RL	2.6	0.9	34.6	LB	3.3	1.8	54.5
HV[3]	2.8	0.6	21.4	TB	3.5	1.8	51.4
AH	2.9	0.7	24.1	GL	3.5	0.2	5.7
CB	7.4	0.7	9.6	EL	7.6	1.6	21.1
Average Movement	2.8 ± 2.0	0.6 ± 0.4	31.9 ± 29.2	Average Movement	2.8 ± 3.0	0.5 ± 1.3	0 ± 95.7

1 Figures rounded to the nearest decimal
2 Bilateral cleft of the alveolus and palate
3 Unilateral cleft of the right alveolus and palate

Subgroups of both the experimental and comparison groups were analysed by separating out cases with surgery only on the maxilla, split maxillae and cases with mandibular surgery to determine if there was any possible effect due to different surgical procedures. Separating the cases in this manner produced no significant differences within or between the groups.

DISCUSSION

Inferior repositioning of the maxilla is a seldom used procedure in clinical orthognathic practice. The probable reasons for the infrequency of the procedure are low demand, due to infrequency of occurrence of short midface, and the fact that downgrafting has proven to be unstable. The number of cases used in this non-randomized study was limited and as a result, meaningful comparisons were difficult.

A significant difference was found when the anterior T1 position of the maxilla was compared to the T2 and T3 positions in the experimental group. When T2 and T3 anterior positions were compared, there was no significant change, suggesting no pronounced relapse. The relapse in the experimental group was measured in absolute change and as a percent relapse. The average anterior relapse was 0.7 $\pm$ 0.6 mm. However, omitting the cleft cases which had the greatest relapse in the experimental group, resulted in; reduced anterior relapse of 0.4 $\pm$ 0.4 mm, reduced range of relapse (0 to 1.2 mm), and reduced percent relapse of 6.1 $\pm$ 5.0%. When amount of relapse was correlated to types of surgery, sex, and age, no significant correlations were found for either group.

In analysing the comparison group, there was no significant difference from T1 position of the maxilla to either T2 or T3 positions for either anterior or posterior measures. As with the experimental group, no significant difference was found when the groups were split into subgroups. In both cases this could be due to the small numbers in the sub-groups.

When percent anterior relapse was compared between the experimental and comparison groups a significant difference was found. The variability within the experimental group is much less than the comparison group for both anterior and posterior relapse.

Reasons for the wider range in variability may be due to differences in stability afforded by each procedure. Lack of stability in the comparison group could be attributed to low compressive strength of the bone graft and its juxtaposition to the thin margins of the osteotomized segments[2]. Another possibility could be that during the time the bone graft is being resorbed and replaced with new autogenous bone, it is unable to support compressive strength of the masticatory muscles[4]. Wessberg and Epker[14] suggested that, according to Starling's law, a stretched muscle has increased contractile strength.

Turvey[15], agreed that relapse is due to overstretched muscles and that the amount of inferior movement must be considered. He pointed out that if the elevator muscles are stretched, the relapse force will be greater and possibly result in more relapse. This study showed no significant relationship of the amount of movement with eventual relapse.

Several studies looked at the vertical stability of downgrafting after wire fixation. Bell and Scheideman[2] had average relapse of 31%, with a range of 0 to 100%, Freihofer[3] and Hedemark and Freihofer[4] reported 50% relapse.

The study by Wolford and Hilliard[5] had a range of relapse from 20 to 70%. The comparison group in this study had similar relapse found in other studies of wire fixation in downgrafting, suggesting bone alone is insufficient to support the segments.

The relapse found in using wire fixation necessitated other attempts to support the downgraft of the maxilla. Freihofer[2] concluded that overcorrecting by 50% would provide a satisfactory result after relapse. In our comparison group the relapse was not uniform. In fact, 2 cases had a vertical increase following surgery and another 2 had relapses of nearly 100%. Therefore, overcorrecting in some cases will not prevent complete relapse and other cases will remain overcorrected after relapse is complete.

Another suggestion by Wolford and Hilliard[5] included Steinmann pins from the zygomatic arch supporting a splint. This would prevent the occlusal force from the mandible being transmitted to the downgrafted maxilla. Other suggestions included use of rigid fixation with mini-plates and screws[1-4].

Plates and screws are intended to stabilize the mobile segment. The plates must either bend or pivot with an angular component allowing the mobile segment to relapse. Another possibility is that the bone may not have compressive strength to support the screws allowing them to move under the relapse force.

In previous studies, relapse using rigid internal fixation was quite variable. Persson et al[9] found an average of 20% relapse in their study and Baker et al[10] concluded that rigid fixation was no better than wire fixation. The differences between our experimental group and these studies are multiple. The surgical procedures in the study by Baker et al[10] were not completed by the same surgeon. Thus, there could be different techniques employed intraoperatively that may allow more relapse. They also reported that not all cases of downgrafting received bone grafts. The authors suggested that the plates were unable to fully overcome the forces of occlusion and that bone grafts for maxillae downgrafted greater than 3 mm should be employed. From this they believe that interposed bone in the osteotomy site, in concert with the plates, may produce more acceptable results. The results of the current study appear to confirm the assumption by Baker et al[10]. It is possible the interposition of bone in all cases of rigid internal fixation may make the procedure less variable.

Another possible difference between amount of relapse in this study and that previously reported in the literature could be the method of cephalometric analysis. Baker et al[10] used landmarks such as A point, incisor tip, PNS, and

ANS. A point is unreliable in the vertical dimension, the incisor can change vertical location due to postoperative orthodontics[13], PNS is difficult to locate and ANS is often removed during Le Fort I procedures. These factors may cause variations in positioning of the maxilla in space for cephalometric analysis and therefore introduce procedure errors. The incisor tip may be the factor that can mimic relapse the most as postoperative elastics can extrude the tooth. If the incisor is being used to locate the body of the maxilla, an extruded incisor will cause A point, ANS and possibly PNS to be placed more superior, and thus mimic relapse.

Persson et al[9] also varied their technique between patients. They reported that in some cases only one screw was placed in the mobile segment and there were either 2 or 4 plates used depending upon the case. None of their cases of downgrafting received bone placed within the osteotomy cut. Instead, bone was simply placed over the osteotomy site and not interposed between segments. Suspension wires from the infraorbital rims were used for MMF in all but 3 cases and there was no mention of the duration of MMF. Average relapse was 20% with a range of 0 to 50%. As with Baker et al[10], Persson et al[9] used the incisor to locate the maxilla. This again could lead to false relapse.

Digitizing films in this study was completed by ignoring tooth structure and relying more on stable structures within the body of the maxilla. These may include the contour of the cortical bone of the oral surface of the maxilla or consistent trabeculae within the maxilla. A better technique would be to employ stable implants on which a more positive superimposition could be achieved. However, by not relying on the incisor, any post surgical tooth movement has been eliminated as a source of error.

It appears there is reasonable stability in the experimental group. A consistent surgical technique was employed in all cases with 4 plates used and 2 screws on both sides of the osteotomy cut. Cortical bone was placed between the osteotomized segment in all cases no matter how little the inferior movement. The fact that bone was interposed in the osteotomy site along with the stability afforded by the plates could explain the differences between our experimental group, the comparison group and downgrafting reported in the literature.

One problem encountered in this study was the small sample size. Surgical downgrafting is an infrequently performed procedure, and in order to increase the sample size, records of more than one surgeon may need to be examined. Caution must be exercised in ensuring that the surgery is consistently performed, and that the cephalometric technique does not use unstable landmarks for digitization. Once differences between surgeons has been eliminated, the effect on age, sex, types of surgery and amount of initial downgraft can be better analysed. A prospective, randomized study would improve the methodology, but due to the rarity of this procedure, it may not be possible.

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CHAPTER THREE - GENERAL DISCUSSION

Downgrafting the maxilla, in its nature, is a difficult problem to study. It is a rare procedure and it is not always completed in a similar manner by different surgeons. It is also difficult to find reproductive cephalometric landmarks in order to measure surgical movement and relapse.

There are many different ways to secure the downgraft. Initially it was completed by placing iliac crestal bone or rib graft between the osteotomized segments, while the patient was placed in maxillomandibular fixation during bone healing. The results of this method proved to be very unpredictable[1-4].

Other methods of fixation have also been attempted. Included in the literature are reports on Steinmann pins[5], or external frames[6] both, unfortunately, reported without measure of relapse. More recently, rigid internal fixation has been studied[7-8]. As well, implants of hydroxyapatite have been used to support the mobile segment[9-10].

Previous studies with rigid fixation may have had flawed methodology due to the difficulty in landmarking in the maxilla, thus the interpretation of their results is suspect. In this study, traditional cephalometric landmarks were not used due to the difficulty in accurately locating them[11]. The method described by Houston et al[11] was used to locate the maxilla for digitizing.

Once the maxilla was located with respect to the anterior cranial base, and the ethmoid triad, measurements were made using a sonic digitizer (Sciences Accessories Corporation, Graf/Pen GP6-3D). The accuracy of the digitizer was confirmed with repeat measures of 5 cm and was found to be accurate to within 0.2 mm (see appendix 1).

This study showed that relapse following downgrafting of the maxilla was more stable with rigid internal fixation as opposed to wire fixation. Stability was seen with reduced variability in relapse in both anterior and posterior measurements of the experimental group when compared to the comparison group.

Significant difference was also seen when the percent anterior relapse in the experimental group was compared to the comparison group. Even though there was not a significant difference in measure of posterior relapse, the variability of posterior relapse is much greater than anterior relapse in both groups. The experimental group posterior relapse varied from 9 to 100% and the comparison group varied from an actual increase in inferior movement (negative relapse) of 188% and a maximum relapse of 137%.

The reason there were three cases of negative relapse in the comparison group could be that an individual case could have been left with a posterior open bite following surgery. Elastics could then have been used to close the bite, pulling the maxilla inferior. With rigid fixation, there is very little chance that the maxilla could be drawn inferior with elastics and therefore, little negative relapse could occur.

There was a strong significant correlation between the anterior and posterior relapse of the experimental group. Notwithstanding the correlation, there was greater absolute relapse, as well as more variability in the posterior measure. A possible reason for this difference is suggested by Turvey[13] where he believes relapse is as much a function of the direction of the relapse force as it is the amount of initial downgraft.

In a case where the mandibular plane is flat, Turvey[13] suggests the direction of pull will be more anterior and thus produce greater anterior relapse. Accordingly, if the mandibular plane is steep, the direction of pull will be more in the posterior aspect of the maxilla, producing greater posterior relapse. Due to the nature of this study, it is possible that all cases in the experimental group had mandibular plane angles that would produce greater posterior than anterior relapse.

Another noted difference between the anterior and posterior relapse in the experimental group is found in the cleft cases. The anterior relapse for the cleft cases were the highest of the experimental group. However, for the posterior, the cleft cases were at the low end of the range of relapse. Though not significant, this may validate the idea that the bone near the cleft site is less dense, or the fact that plating near the cleft is not ideal.

Other procedures have shown some success in downgrafting the maxilla. These included the use of porous hydroxyapatite placed within the osteotomized site. Rosen and Ackerman[2] studied 76 patients undergoing LeFort I procedures of which 10 had inferior repositioning. They found an average relapse of 4.5%, with 3 patients demonstrating slight inferior movement (negative relapse). They also found that the greatest amount of relapse was 0.5 mm but make no statement as to the percent relapse of the case. Unfortunately, they present no other data such as the range of relapse found or the average amount of inferior movement. They also used standardized hard tissue cephalometric landmarks to determine stability of inferior placed maxillae. As previously noted, standardized landmarks are not stable in the vertical dimension[11]. The inferior repositioning following surgery could actually have been due to landmark error.

Wardrop and Wolford[10] also looked at stability of downgrafting using rigid internal fixation and hydroxyapatite. Their study showed relapse of 9% in the anterior and 12% in the posterior. Five of the patients had previously repaired cleft lip and palates which did not appear to make a significant difference in relapse. The range of relapse for the anterior was similar to this study ranging from 0 to 18%. The range of posterior relapse with hydroxyapatite ranging from 0 to 17% was much less than this study.

It is possible that a foreign body such as hydroxyapatite can cause postoperative infection, sequestration, or result in fibrous union between the bone and implant. Neither of these studies found significant problems with hydroxyapatite implants. In fact, Wardrop and Wolford[4] found bone ingrowth into the pores of the implant, suggesting good biocompatability.

No other method of downgrafting has proven to be as stable as those suggested by these two studies or by the study presented here. This study suggests that downgrafting with iliac crestal bone grafted into the osteotomized site with four mini-plates for fixation is as stable as using porous hydroxyapatite.

One of the problems encountered with this study is the small sample size. It was purposely completed in this manner in order to eliminate any possible differences between different surgeons. However, it may be necessary to use a multicentre study in which more than one surgeon completes cases in the experimental group.

A multicentre study may also address other potential problems. A prospective study may be possible with a larger group of surgeons from which to choose subjects. Once large enough numbers are achieved, differences between types of rigid internal fixation and different surgeons, can be examined. As well, a prospective study, with a large enough sample base may have the luxury of applying randomization of cases to two or more treatment methods.

Without improved methodology, it would still be of interest to analyse the subjects in this study to determine if there is a difference in relapse with a change in the mandibular plane angle. An analysis of this sort may prove, or disprove, Turvey's[13] hypothesis. If it is proved that a flat mandibular plane does result in increased anterior relapse, the surgeon may be better equipped to deal with the potential relapse with improved surgical planning.

From the results in this study, it would appear that stability of downgrafting, using autogenous bone graft and rigid internal fixation, is satisfactory enough to offer as a viable alternative to patients with vertical maxillary deficiency.

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APPENDIX 1: TEST MEASURE AT 5 CM

TEST MEASURE 1 SEPT 2, 1993	TEST MEASURE 2 SEPT 4, 1993	TEST MEASURE 3 SEPT 5, 1993	TEST MEASURE 3 SEPT 7, 1993
4.97	4.95	5.01	5.02
4.98	5.00	5.00	5.01
4.97	5.00	5.00	4.99
5.00	5.02	5.00	5.00
5.01	5.04	4.99	4.98
4.98	4.98	5.01	5.00
4.99	5.01	5.00	4.99
5.00	5.01	5.00	5.01
4.98	5.00	4.98	4.97
5.00	5.00	4.99	5.01
5.00	5.01	5.00	5.02
5.00	5.01	4.98	4.99
4.98	5.01	5.03	5.01
5.01	5.03	4.98	4.99
5.00	5.02	4.99	5.00
5.00	5.02	5.00	5.01

Average = 5.0 ± 0.02 cm

APPENDIX 2: MEASUREMENT DATA FOR EXPERIMENTAL AND COMPARISON GROUPS

Experimental

Name	Ant mm	Pos mm	Date	Ant Inf Mvt mm	Ant Relapse mm	Pos Inf Mvt mm	Pos Relapse mm
RL	58.6	46.8	Preop				
	60.2	49.4	Postop	1.6	0	2.6	0.9
	60.2	48.5	38 mo				
DD	51.6	42.4	Preop				
	56.1	44.5	Postop	4.5	0.4	2.1	0.8
	55.7	43.7	12.5 mo				
HV	59.7	45.0	Preop				
	64.8	47.8	Postop	5.1	0.9	2.8	0.6
	63.9	47.2	6 mo				
AH	58.6	48.4	Preop				
	64.7	51.3	Postop	6.1	0.7	2.9	0.7
	64.0	50.6	7.5 mo				
AG	49.7	45.1	Preop				
	56.0	44.0	Postop	6.3	0.1	-1.1	2.0
	55.9	46.0	11 mo				
MD	58.3	48.2	Preop				
	65.0	49.0	Postop	6.7	2.3	0.8	0.1
	62.7	48.9	16.5 mo				
AW	50.5	38.1	Preop				
	58.3	35.1	Postop	7.8	0.4	-3.0	-0.4
	57.9	34.7	19 mo				
CB	58.0	45.8	Preop				
	65.9	53.2	Postop	7.9	1.2	7.4	0.7
	64.7	52.5	37 mo				
BF	49.9	39.6	Preop				
	58.6	40.9	Postop	8.7	0.6	1.3	1.5
	58.0	39.4	8.5 mo				
SD	57.2	48.7	Preop				
	65.9	50.7	Postop	8.7	0.2	2.0	0.3
	65.7	50.4	12.5 mo				
SC	64.6	53.4	Preop				
	76.4	47.4	Postop	11.8	0.4	-6.0	-0.3
	76.0	47.7	8 mo				

Comparison Name	Ant mm	Pos mm	Date	Ant Inf Mvt mm	Ant Relapse mm	Pos Inf Mvt mm	Pos Relapse mm
JM	58.6	51.4	Preop				
	59.4	52.3	Postop	0.8	-0.2	0.9	-1.7
	59.6	54.0	39 mo				
GL	65.2	58.1	Preop				
	67.3	61.6	Postop	2.1	1.0	3.5	0.2
	66.3	61.4	6 mo				
LB	50.7	42.8	Preop				
	52.8	46.1	Postop	2.1	1.3	3.3	1.8
	51.5	44.3	35 mo				
TP	52.3	50.8	Preop				
	55.0	49.5	Postop	2.7	0.9	-1.3	0.3
	54.1	49.8	32 mo				
MH	54.8	47.9	Preop				
	57.8	48.7	Postop	3.0	2.8	0.8	1.1
	55.0	47.6	12 mo				
TD	55.7	40.4	Preop				
	58.9	42.3	Postop	3.2	1.9	1.9	-0.6
	57.0	42.9	13 mo				
EW	52.1	39.4	Preop				
	55.4	40.0	Postop	3.3	2.8	0.6	-0.3
	52.6	40.3	27 mo				
WM	60.3	54.5	Preop				
	63.7	53.7	Postop	3.4	-0.1	-0.8	2.7
	63.8	51.0	17 mo				
TB	61.6	50.5	Preop				
	67.8	54.0	Postop	6.2	3.5	3.5	1.8
	64.3	52.2	13 mo				
MW	48.5	46.1	Preop				
	57.7	44.7	Postop	9.2	3.9	-1.4	1.1
	53.8	45.8	17 mo				
EL	56.1	44.0	Preop				
	69.1	51.6	Postop	13.0	8.5	7.6	1.6
	60.6	50.0	15 mo				