AN EVALUATION OF LONG-TERM OCCLUSAL STABILITY FOLLOWING COMBINED ORTHODONTIC AND ORTHOGNATHIC SURGICAL TREATMENT

by

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Submitted in partial fulfillment of the requirements
for the degree of Masters of Science in Dentistry

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Abstract

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The prevalence of clinically significant, long-term occlusal change following combined orthodontic and orthognathic surgical treatment was estimated. Self-administered bite registrations were analyzed for the presence of any one of five occlusal criteria, each of which would indicate that moderate to severe, long-term, post-surgical occlusal change had occurred; these criteria included the presence of an anterior open bite, anterior cross-bite, posterior open bite, posterior cross-bite or a 5 mm or greater overjet.

An estimated prevalence of 12.9% was found based upon 132 subjects with an average post-surgical follow-up of 9.1 years. Stratification of the data indicated that five variables were more common to the group of patients exhibiting excessive long-term, post-operative occlusal

change. These variables included: age of less than twenty years; a pre-operative maxillomandibular relationship of either mandibular retrognathia with a concomitant open bite, vertical maxillary excess or maxillary constriction; surgeon; having undergone bimaxillary surgery; and having had rigid fixation.

DEDICATION

For Mike, Katharine and Aubrey

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are deserving of the highest professional accolades for their role in expanding the collective knowledge base of our professions.

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INTRODUCTION

Condylar resorption, also called condylar atrophy or condylar necrosis, has long been recognized as a potential, albeit rare, sequelae to orthognathic surgery which could play a causative role in relapse over the longer term (104). Recently, however, Cassidy and his co-workers in St. Louis reported that three of twenty six adult patients who had undergone orthognathic surgery to correct a Class II Division I malocclusion exhibited "extensive relapse, probably the result of condylar resorption" (26), a finding that was extraneous to the intent of the study undertaken and, thus, was not subject to good statistical methodology. Nonetheless, this was a very compelling finding since most previous reports of post-surgical condylar resorption were primarily, though not exclusively, isolated case studies or very small case series (2, 64, 69, 71, 104, 132, 170). Despite the small number of reports linking condylar resorption to long-term clinical relapse following orthognathic surgery, the findings of Cassidy and his co-workers, if even an approximate representation of the prevalence of post-surgical relapse secondary to condylar resorption, indicate the possibility that this type of

relapse has gone either relatively unrecognized or simply underreported. It is with this in mind that a preliminary study to determine the prevalence of significant long-term occlusal change was undertaken.

The primary purpose of this study is to estimate the prevalence of clinically significant, long-term, post-surgical physiologic change as exhibited by certain potentially condyle-related parameters seen in clinically unacceptable occlusal relationships. To this end, a self-administered technique of accurately registering these key occlusal parameters was developed and tested. Subsequently, the surgical records of two hundred ninety four patients treated with a combination of orthodontics and orthognathic surgery at least five years previously for their maxillomandibular disharmonies were screened for inclusion in the study. One hundred forty six of these persons agreed to participate in the study and were sent occlusal registration materials. Ultimately, one hundred thirty two people returned the materials which were then measured and evaluated. An estimate of the prevalence of clinically significant, long-term physiologic change was then made.

REVIEW OF THE LITERATURE

Relapse, broadly defined here as the tendency of the components of the dentofacial complex to return to their pre-treatment state, can occur after either orthodontics alone, surgery alone or combined orthodontic-surgical treatment. Relapse after combined orthodontic-surgical treatment can be skeletal and/or dental and can be temporally described as immediate (at fixation release), short-term (within six months after fixation release) or long-term (six months post-fixation release or beyond) relapse. Eventhough the intent of the present research study is to attempt to quantify the presence of long-term physiologic change after orthodontic-surgical treatment as observed in the dental relationships, an individual's occlusion can be considered a positional equilibrium based upon the magnitude and direction of the forces acting on the functional dentition, and this, in turn, is almost certainly dependant upon the skeletal base on which the teeth rest. Dental equilibrium is dependant upon skeletal equilibrium and, thus, the present review of post-surgical relapse must include both components.

Post-surgical relapse has been the topic of much

scientific speculation and research and has generated an almost cumbersome amount of literature. No attempt has been made to include every article written on a given surgical movement but, rather, an attempt to present a selection of the most well-designed and well-reasoned literature has been made as well as to include those authors who are most prolific in their writings on the topic or who have well-known expertise on the topic.

Mandibular Advancement

The modern history of surgical mandibular advancement can be traced back to Blair, a professor of oral surgery in the Dental Department of Washington University in St. Louis who, in 1909, published a landmark article on the surgical treatment of the "underdeveloped lower jaw" (17) which involved cutting both mandibular rami horizontally via an extraoral approach, "stretching" the muscles of mastication, advancement of the distal segment to an overcorrected position and fixation. Two case reports were presented, both with compelling pre-surgical and post-surgical photographic documentation.

At the present time, the sagittal split osteotomy of the mandibular ramus is the most commonly utilized technique for surgical mandibular advancement. Developed

in Switzerland, it was first introduced in the United States by Trauner and Obwegeser in 1957 (145) and has undergone numerous subsequent modifications (30, 65, 52, 39, 13, 18, 166) in order to simplify the surgical procedure or to reduce its associated morbidity.

Stability has long been a concern with any surgical correction of mandibular retrognathia (86) and it is no less so with the sagittal split osteotomy. There are basically three mechanisms by which post-operative movement of the distal segment back toward its original position following a sagittal split advancement can occur: bodily movement subsequent to condylar displacement at the time of fixation, movement or bone loss at the site of the surgical bone cuts and post-surgical mandibular remodelling. The effects of the first two mechanisms of relapse are seen either immediately following fixation release or within the first six months post-surgery, assuming normal bone healing. The effects of bony remodelling, including physiologic condylar remodelling, pathologic condylar resorption and dentoalveolar remodelling, are clinically demonstrable only after long-term evaluation.

A number of factors have been implicated or espoused as contributing to the degree of relapse seen after surgical mandibular advancement. These include age (83, 93, 130), sex (83), pre-operative mandibular plane angle

2(67, 83, 103, 129, 169), facial morphology (83, 53), magnitude of advancement (20, 44, 64, 67, 83, 92, 116, 103, 126, 150, 151, 162), connective tissue tensile forces (25, 37, 43, 44, 45, 54, 67, 73, 83, 91, 92, 106, 116, 139, 158), increased posterior face height (20, 83, 129, 158, 170), proximal segment rotation (44, 46, 66, 73, 83, 129, 161, 170), individual surgical experience (129), pre-operative orthodontic treatment (44, 158), duration of intermaxillary fixation (43, 73, 93, 129, 158, 170), fixation type (38, 43, 66, 72, 73, 87, 91, 112, 116, 124, 129, 136, 149, 156, 158) and condylar displacement (37, 43, 44, 50, 66, 73, 83, 105, 124, 129, 130, 139, 152, 158, 161, 170).

In 1971, Poulton and Ware (105) were the first authors to quantify relapse following sagittal osteotomies for mandibular advancement and were the first to report findings of skeletal relapse occurring during intermaxillary fixation when occlusal changes were impossible. In a follow-up article in 1973 (106), they emphasized the role of the suprahyoid muscles in skeletal relapse and advocated the use of a Pitkin collar post-operatively. Two patients that did not use the neck brace postoperatively exhibited a mandibular skeletal relapse of 50% to 80% while three patients who did wear the brace had mandibular skeletal relapse rates of 8% to 30%. The

majority of the relapse was seen in the first six months after surgery. In 1973, McNeill, and his colleagues in Seattle (93) cephalometrically evaluated relapse during intermaxillary fixation and found mandibular skeletal relapse rates of 33% to 62% with intermaxillary fixation alone (n=3). In a severe Class II open bite case in which a sternal-mandibular traction brace and a posterior bite opening surgical splint were utilized, a 27% horizontal relapse and a 100% anterior vertical relapse of the mandible was seen during fixation. The authors recommended surgical overcorrection for mandibular advancement patients who did not have an open bite and recommended maximizing distal segment rotation with a posterior bite opening surgical splint plus the use of vertical extra-oral traction in the post-operative healing period in open bite cases. The authors suggested that detachment of the geniohyoid or digastric muscles may also aid in preventing mandibular skeletal relapse.

That same year, Steinhauser (139) reported that myotomies of the geniohyoid, anterior portions of the mylohyoid and the anterior bellies of the digastric muscles had been performed on six high angle Class II open bite patients who had undergone concomitant sagittal split osteotomies. Findings were not reported as he felt that the patients should be re-evaluated for at least three

years post-operatively prior to judgement of the efficacy of the adjunctive procedure.

It should be pointed out that all of these authors recognized the potential role of condylar distraction in relapse. Poulton and Ware recommended that intraosseous wires "be placed so that the condyles are firmly seated in the glenoid fossa." (106) McNeill and his co-authors (93) examined ramus position cephalometrically before and after surgery and saw no change that may have indicated that condylar distraction had occurred. They further noted that in three of the cases, the proximal segment moved anterosuperiorly, not posteriorly. Steinhauser (139) noted that the proximal segment could be easily pulled out of the fossa and offered specific intraoperative methods to prevent this from occurring.

The following year Guernsey (54) reported on six mandibular advancement cases, five sagittal split osteotomies and one C-osteotomy. Relapse among the sagittal split cases ranged from 25% to 50% and antero-posterior relapse in the C-osteotomy case was 25%. The author felt that the use of cast arch bars for intermaxillary fixation instead of the usual orthodontic wires decreased the relapse tendency during fixation.

In 1975, Friehofer and Petresevic (50) evaluated thirty eight patients who had mandibular advancements via

sagittal split osteotomies at least two years previously (mean = five years). Among the parameters evaluated were the stability of occlusion, via both clinical observation and model analysis, and a comparison of cephalometric radiographs taken pre-operatively, immediately post-operatively and at long-term follow-up. Because of concomitant anterior mandibular surgical procedures, skeletal markers used for interradiographic comparison were moved and thus the radiographs were only subjectively evaluated. Change in occlusion constituted occlusal relapse while radiographic and clinical assessment of esthetic changes were used to evaluate skeletal relapse. Occlusally, 68% showed minimal changes, defined as less than 1 mm of change in overjet, 21% showed up to 3 mm change in overjet, half of whom the authors felt were due to placing the patients in an unstable "cusp-to-cusp" occlusal position during surgery. Eleven percent relapsed to 40% or more of the advancement, one of whom relapsed 100% and was resurgerized only to relapse 66% the second time. The authors did not state whether these four cases had an unesthetic result and therefore, presumably, a significant skeletal relapse. Though no statistical data was presented, the authors found that the experience level of the surgeon had no relationship to the results of surgery except with regard to positioning the condyle

during surgery. Three cases that necessitated reoperation due to condylar distraction as determined by post-surgical radiographs had been operated on by "surgeons in training." Also, the age of the patients was felt to have no influence on the probability of success of the surgery.

In 1977, Ive, McNeill and West (67) evaluated serial cephalograms of twenty-one patients who had been treated by surgical advancement via bilateral sagittal split osteotomies. Standardized lateral cephalographs were taken pre-surgically, within forty eight hours post-surgically, approximately three weeks post-surgically and after release from fixation. Intra-operatively, condyles were manipulated to their most postero-superior position in the fossa and then intraosseous wires, the exact technique of which was not stated, were placed to hold them in that position. Intraosseous and intermaxillary fixation was supplemented with extraoral traction via a soft cervical collar. All twenty one patients exhibited skeletal relapse during fixation with most, but not all, occurring in the first three post-operative weeks. In order to evaluate the role of suprahyoid muscular displacement in skeletal relapse, they attempted to correlate amount of advancement to amount of relapse. They found relapse rates of 11% to 71% with a positive correlation between advancement and absolute relapse but not with relative relapse. There was

no correlation between relapse and mandibular plane angle with their sample exhibiting mandibular plane angles of 21 to 46 degrees (mean = 36.4) but not including patients with anterior open bites. There was no correlation between the age of the patient and relapse and there was no correlation between the presurgical dental pattern and compensatory dental change. The authors concluded that causes of mandibular skeletal relapse were multifactorial.

That same year, Barton (4) evaluated relapse following sagittal split advancement both cephalometrically and on models. The cephalometrically evaluated group was composed of fourteen patients with a mean advancement of 7.6 mm and who had a mean relapse at three months of 1.6 mm (21%) and a mean relapse at one year of 1.8 mm (23%). The models of twenty four patients showed a mean advancement of 7.3 mm with a mean relapse of 29% at three months and 30% at one year. There was no relationship between age of the patient or the amount of the advancement and the amount or degree of relapse. These occlusal findings must be viewed within the context of what was measured - the mean distance between the distolingual cusps of the first or second molars and pre-determined soft tissue reference points in each arch. Changes in overjet or Angle classification were not measured and, as such, no conclusions can be drawn regarding the stability of the interocclusal relationships.

The following year, Isaacson and his co-workers looked at the role of the proximal segment in mandibular surgical relapse (66). Serial cephalograms and laminographs of six sagittal split advancement patients and three C-osteotomy advancement patients were evaluated. Acrylic posterior bite-opening splints were used in those cases where a distal segment counterclockwise rotation was needed. The proximal and distal segments were secured with intraosseous wires in ten patients, with a form of rigid fixation utilizing a wire mesh overlay with at least two screws in each segment in two patients and no intraosseous fixation was placed in fifteen patients. The authors found no evidence of proximal segment rotation during surgery but they did find a mean 2.2 mm inferior displacement of the condyles with a 1.2 mm mean anterior displacement. After a mean advancement of 8.7 mm, a mean relapse of 43% was seen. The authors emphasized that in cases where the proximal and distal segments were not fixated intraosseously, the condyles returned to a position of equilibrium during intermaxillary fixation and thus, no occlusal changes were seen at fixation release. On the other hand, occlusal open bite relapse was evident in the first few days following release from intermaxillary fixation in cases where intraosseous fixation was used. The data reported in this article should probably be

interpreted with care given the small number of patients, the authors' admission that each series of radiographs was not necessarily complete for each patient, the large standard deviation for the reported means, the known difficulty in accurately reading condylar outlines in cephalograms and non-corrected tomograms and the potential for condylar torquing and/or horizontal rotation during placement of intraosseous fixation that could be interpreted two-dimensionally as condylar displacement. Nonetheless, the fact that, in at least some of the patients, occlusal open bite relapse was noted to occur shortly after release of intermaxillary fixation is de facto evidence of relatively significant condylar displacement.

The overall effect on relapse of eliminating intraosseous fixation in order to avoid problems of condylar sag was evaluated by Sandor and his colleagues in the Netherlands (124). In 1984 they published a comparison of forty sagittal split osteotomy patients, half of whom had intraosseous fixation with a single superior border wire and half of whom received no intraosseous fixation. Both groups were treated to an approximately twenty percent overcorrected Class I canine relationship and were placed in a posterior bite-opening splint for the duration of six weeks of intermaxillary fixation as well as two to six

weeks post-fixation during which time the splint was serially ground in the posterior to guide molar eruption. All patients wore a soft cervical collar throughout the fixation period and for approximately four weeks afterward. Standardized lateral cephalograms were taken of every patient at pre-surgery, one or two days post-surgery, at fixation release and at long-term follow-up (minimum of one year). Both groups were advanced a mean of 6.1 mm. The intraosseously fixated group exhibited 23% relapse, 10% from the immediate post-operative period to fixation release and 13% from fixation release to the long-term. The group without intraosseous fixation, on the other hand, exhibited 77% relapse with the majority of relapse occurring between the post-operative period and fixation release though the relapse continued to a lesser extent into the long-term. Condylar distraction was a problem in the non-osteosynthesis group but was not evident in the intraosseous fixation group. Interestingly, all twenty patients in the non-osteosynthesis group showed a lateral flaring of the proximal segments which gradually moved medially for four months post-surgery.

In 1978, Epker and his colleagues (44) essayed the factors they considered important in relapse of mandibular advancements. These "pearls" were eightfold:

a) Unstable orthodontic tooth movement as well as large amounts and/or rapid tooth movement could lead to skeletal relapse during intermaxillary fixation. In fact, the authors stated that in cases without tooth mobility, skeletal relapse during intermaxillary fixation "is minimal".

b) The position of the ascending ramus and muscles of mastication should be unaltered spatially during advancement. If the ascending ramus is altered in size, shape or spatial orientation, the muscles of mastication should be completely detached, except for the lateral pterygoid.

c) When the advancement lengthens the suprahyoid muscles by greater than fifteen percent of their resting length, the anterior digastrics and the geniohyoid should by surgically detached from the mandible as part of the advancement procedure.

d) The larger the advancement, the greater the potential for relapse.

e) When a counterclockwise rotation is included as part of the advancement, an occlusal splint that horizontally and vertically overcorrects the deformity should be employed during fixation.

f) Relapse that occurs during and immediately upon removal of the intermaxillary fixation is quite likely the result of failure to reposition the condyles properly into the fossa and are, thus, "technical failures". Intraosseous fixation which "firmly repositions the condyle postero-superiorly into the articular fossa when tightened" should be employed.

g) When teeth are loose, the advancement is large or there is a counterclockwise rotational movement of the mandible during the procedure, skeletal fixation should augment the intermaxillary fixation; and

h) Excessive stripping of muscle attachments to the proximal segment as well as other procedures that may delay osseous union should be avoided.

No data was offered in this article to support the cogency or efficacy of any of these suggestions.

In comparison to the previous essay, that same year Kohn (73) analyzed seventeen cases for relapse after mandibular advancement. Standardized lateral cephalograms taken pre-operatively, within twenty four to forty eight hours post-operatively and at fixation release were evaluated. Twelve of these cases were also evaluated for long-term changes with radiographs taken from six months to four years post-operatively (mean = two years). Rotational changes in the condyle were differentiated from translational changes by evaluating changes in constructed gonial arc measurements while changes in the antero-posterior position of the proximal segment were evaluated relative to the pre-operative sella-gonion axis. Among a number of interesting findings, the strongest relationships were found between posterior relapse measured at gnathion and changes in gonion relative to the gonial arc, which was a measurement of condylar displacement. Eventhough efforts were made during surgery to prevent condylar displacement, it seemed to have occurred. Four of the seventeen patients showed no anterior or inferior movement of the proximal segment during surgery and these patients showed little or no mandibular relapse. Of these four patients, two were evaluated in the short-term while the other two were long-

3term evaluations. Intraoperatively, there was concerted manipulation of the condyle into the fossa to its most postero-superior position which was then stabilized with intraosseous wire fixation. Kohn noted that if this wiring was effective, the condyles could not have been completely seated and thus greater attention should be placed in manipulation of the proximal segment into its proper position. On the other hand, if the condylar displacement occurred after the transosseous wires were placed, then a more effective, more "rigid means of fixation" between the segments was necessary. No relationship between relapse and mandibular plane angle, pre-operative orthodontic treatment or type of surgery (sagittal split, C-osteotomy or modified C-osteotomy) was found.

In 1980, Kundert and Hadjanghelou (81) looked at condylar displacement after sagittal split osteotomies for correction of mandibular prognathia or mandibular retrognathia. Pre-operative and post-operative individualized lateral oblique radiographs from thirty five patients were evaluated for amount, frequency and direction of condylar changes between the two time periods. Interestingly, PA cephalograms and linear tomograms were also taken pre-operatively and post-operatively for each patient but were not evaluated due to the inability to accurately reproduce serial projections. The authors found

that after mandibular advancement, narrowed joint spaces and posterior displacements were found more often than were seen pre-surgically. Displacement of the condyles with rotation or tilting predominated and did not correlate with the direction of mandibular movement during surgery or the type of osteosynthesis used (circumferential wire vs. screw fixation). There were as many medial rotations of the condylar axis as lateral rotations after advancement of the mandible. Mandibular advancements produced greater displacements than set-backs and only seven condyles were not displaced during surgery. Screw fixation produced greater displacements than circumandibular wire fixation. This was seen eventhough screw fixation was only used when the proximal and distal segments could be adapted without force. The authors did point out that, because of muscle relaxation during general anesthesia, muscle forces could not be evaluated in determining facility of adaptation of the two segments. This study did not evaluate skeletal relapse so no correlation could be accurately made between relapse of the distal segment and the observed condylar displacements.

Also that year, Worms and his colleagues (170) essayed factors they felt were critical to successful outcomes with orthognathic surgery, with emphasis placed on stability of the surgical result. Condylar displacement was discussed

at length. Pre-operative and immediate post-operative laminographs of both condyles were advocated and if the condyles were seen to be improperly placed, immediate resurgery was deemed necessary. Condylar resorption was also discussed as a factor in longer-term instability and one case was presented. The authors stated their opinion that resorption was most likely to occur in mandibular advancement procedures that involve a counterclockwise rotation. Interestingly, the case presented was fixated with "...metal mesh which was fixed with four screws on each ramus...". The authors also stressed the need for the treating orthodontist and surgeon to utilize gnathologic concepts in treating surgery patients, especially when the vertical dimension may be altered. The accuracy of hinge-axis transfer recordings and use of semi-adjustable articulator for the fabrication of splints and positioners or when major occlusal equlibrations are to be done was emphasized. The final aspect of treatment stability that they discussed was the possibility of insufficient calcification or fibrous unions at the surgical site at the time of fixation release.

In a 1980 study of eighty seven mandibular advancement patients from eleven different centers, Schendel and Epker (129) analyzed a number of variables to determine factors that contributed to relapse or its prevention via computer

morphometric analysis of immediate pre-operative, immediate post-operative and follow-up (minimum of twelve months) cephalometric radiographs. Relapse was evaluated as the percentage change in B point. Results were grouped as those cases exhibiting excellent stability (less than twenty five percent relapse), moderate stability (twenty five percent to fifty percent relapse) or severe relapse (greater than fifty percent change). The findings showed twenty seven patients having excellent stability, thirty demonstrated moderate relapse and thirty patients had unacceptably severe relapse. Interestingly, the group demonstrating excellent stability over the long-term had the largest mean mandibular advancement with the group demonstrating severe relapse having the smallest. Nonetheless, stable results were seen in all degrees of advancement. The authors pointed out, however, that small advancements can have acceptable esthetic results, even with a large percentage of relapse since it can be dealt with overcorrection, dental compensations during fixation or by post-surgical orthodontic treatment. The opposite holds true for large advancements; a smaller degree of relapse is a much greater absolute relapse and cannot be compensated as successfully. High mandibular plane angles, change in mandibular plane angle, i.e., a surgical counterclockwise rotation, and post-operative cervical

spine angle were all positively correlated with relapse. Increasing posterior facial height had the highest correlation with relapse. The authors noted that specific surgeons had predictably good or unacceptable results and concluded that, "it is not the nature of the deformity that determines success or failure but rather the specific manner in which the surgery is performed." The authors emphasized the importance of controlling the proximal segment to prevent subsequent relapse and considered both condylar distraction and a counterclockwise proximal segment rotation as critical aspects of this control. They also emphasized the role of fixation in condylar distraction. Exact numbers of open bite cases were not given, nor was their range of treatment success but it was pointed out that significant open bites were successfully closed in four patients treated by the same surgeon using a technique unique to that surgeon which included skeletal as well as intermaxillary fixation that averaged 9.4 weeks (range of seven weeks to eleven weeks, with the seven week fixation case showing "a large relapse"). Also noted were three cases that were stabilized with cervical collars for sixteen weeks post-surgically in which two of the cases actually showed further anterior positioning of the mandible during the follow-up period with the third exhibiting minor relapse. Regarding the role of suprahyoid

myotomy, there was no statistical difference found in the amount of relapse between those cases treated with and without myotomies. The authors did note that the numbers in the myotomy group were not large enough to detect small differences in relapse, that those patients who had myotomies exhibited a more normal post-operative head extension and, therefore, had an increased relapse force to the mandible.

In 1981, Lake and his colleagues in Seattle (83) performed retrospective cephalometric evaluations of fifty-two patients who had undergone surgical mandibular advancements via bilateral sagittal split osteotomy. No other surgical procedures, including genioplasty, were performed on any of the patients in this cohort. Patient age ranged from eleven to forty seven years and the follow-up period ranged from two to almost nine years with an average follow-up of 2.6 years. During surgery, proximal segments were retruded into their most posterosuperior position and high-low wire fixation was utilized to force the proximal segment posteriorly and superiorly. Intermaxillary fixation was placed for approximately six weeks, an occlusal splint was utilized to position the teeth into a Class I canine relationship and this, along with the use of a cervical collar was maintained until two successful cephalograms demonstrated no relapse was

occurring. No other measures were utilized for control of relapse. The authors found that almost 79% of the patients showed relapse between the post-operative cephalogram and the cephalogram taken at fixation removal which averaged 26% of the surgical advancement. During the time period between release of fixation and long-term evaluation, relapse continued in twenty five patients, the mandible advanced in twenty six patients and there was no change in one patient. An average of 75% of the surgical advancement was seen at the long-term evaluation. Two patients showed no relapse at any time interval evaluated. The authors found a moderate association between the absolute amount of advancement and relapse as well as a moderate association between gonial arc changes and relapse both from post-surgery to fixation release and from fixation release to long-term. Patients with increased posterior facial height post-surgery had significantly more relapse during fixation than those whose posterior facial height decreased or remained the same. Age of the patient was not found to correlate with relapse and there was only a weak association between pre-operative mandibular plane angle and relapse. The authors noted some dental changes that occurred over the time frame evaluated. Before surgery, the average overjet was 8.7 mm (range of +4.0 to +13.9 mm) and a post-surgical average of 1.6 mm which was stable

through fixation but showed changes over the long-term; the final mean overjet was 3.3 mm (range of +1.5 to +7 mm). Pre-operative overbite ranged from +11.5 to -1.4 mm with a mean of +4.6 mm. Minimal overbite was "typically present" post-surgery and at fixation release but increased to a mean of +2.9 mm (range of -0.2 to +6.4 mm) over the long-term. Two patients exhibited dental anterior open bite pre-operatively and one patient had an open bite at the long-term evaluation.

Also in 1981, MacIntosh (90) published an evaluation of his experience treating 155 patients with sagittal split osteotomies, thirty nine percent of whom had mandibular retrognathia. Details of the manner in which radiographs or models were evaluated were sparse and only descriptive statistics were given. With regard to relapse, the author did look at changes in chin position cephalometrically but did not separate prognathic cases from retrognathic cases in his description. He also did not state how the cephalometric radiographs were superimposed or from exactly which points measurements were made. The author's conclusion from the cephalometric data was that the "aesthetic compromise is not as frequently significant as the functional compromise." Relapse was primarily evaluated by changes in occlusion. The overall occlusal relapse rate was found to be 29.2% in the mandibular

retrognathic patients with 16.7% exhibiting up to 1 mm antero-posterior or vertical change, 6.25% showing 1.0 to 2.5 mm change and 6.25% having more than 2.5 mm change. It was found that 50% of these patients with occlusal relapse also had a pre-operative diagnosis of apertognathia and all but one of the patients with greater than 2.5 mm of occlusal change had a skeletal open bite. Of the patients showing the most severe occlusal relapse, half of them were retreated (three of six), one "should have" been retreated and the others had their occlusion compensated via equilibration, orthodontics or prosthetic restoration. The author did not correlate relapse with condylar position in any regard but did note that five cases of condylar malpositioning were found at the post-operative radiograph and three were immediately retreated. MacIntosh also found 5.7% of his cases exhibited a delayed union of the surgical segments, the majority of which were in patients over 40 years old, though he did not relate this delay to relapse. Relapse, he theorized, was due to a "proprioceptive drive" to re-establish the pre-operative equilibrium of the dento-orofacial complex.

In 1984, Will and co-workers (161) evaluated condylar position in relation to relapse of forty one sagittal split osteotomy patients, operated on by the same surgeon, having had intraosseous and intermaxillary fixation and

supplemented with soft cervical collar wear. Very little condylar movement was seen post-operatively, an average of less than 1 mm, but the condyles were seen to move superiorly during fixation. The distal segment was advanced and anteroinferiorly rotated during the surgical interval while significant posterior relapse with continued rotation was seen during fixation. Individuals showing the most relapse during fixation showed more counterclockwise condylar inclination during surgery, therefore suggesting that proximal segment inclination may be important in relapse. The group averaged 37% relapse eventhough minimal condylar movements were seen and the authors concluded that relapse is multifactorial.

Also that year, Greebe and Tuinzing (53) evaluated twenty four mandibular advancement patients via both cephalometric and model analysis of pre-operative and one year post-operative records. Though no statistical analysis was done, they found that the posterior face height to anterior face height ratio was a predictor of dental and skeletal stability with patients having a ratio of 72% or more showing dental and skeletal stability, those having a ratio between 66% and 72% exhibiting skeletal relapse but no occlusal relapse and those with a ratio less than 66% showing both dental and skeletal relapse.

Wade, in 1988 (152), evaluated relapse in twelve

patients who had surgical advancements, many with concomitant surgical procedures, but who also had two titanium implants placed in the left proximal segment and two placed in the left distal segment prior to surgery. At the time of intermaxillary fixation removal six to eight weeks post-surgery there was an average 19% relapse, reducing the mean advancement from 14.4 mm to 11.3 mm. Relapse from the time of fixation release to six months post-surgery was another 1% and long-term relapse, at least two years post-surgery, was an additional 7% for a total mean relapse of 27% of the original surgical advancement. Condylar displacement was noted on the immediate post-surgery films in eleven of the twelve cases with a mean displacement of 1.66 mm, always inferiorly and usually somewhat forward as well. It did not appear as if condylar superimpositions of the long-term radiographs were used since no data was reported and the author stated that he believed that the long-term relapse appeared to be "a physiologic muscular adaptation...". Measurements between proximal and distal implants showed little change from the preoperative lengths to the fixation release lengths with five patients exhibiting no change and seven patients exhibiting less than 1 mm change indicating remarkable stability between the surgical segments with superior border wires and intermaxillary fixation.

In 1989, Phillips and his colleagues in Chapel Hill (103) radiographically and clinically examined seventy six mandibular retrognathic patients who had been corrected with bilateral sagittal split osteotomies with intraosseous and intermaxillary fixation, with or without genioplasty. Thirty eight patients had advancements less than or equal to 5 mm and thirty eight patients had advancements greater than 5 mm at B point. During fixation B point moved posteriorly more than 2 mm in 23 patients (30%) and anteriorly in two patients (2.6%) From fixation release to one year post-surgery B point moved anteriorly, on average, resulting in a mean net relapse of approximately 0.5 mm. Fifteen patients (20%) did demonstrate greater than 2 mm net posterior movement while 11 patients (15%) showed more than 2 mm net anterior movement of B point. Neither age nor pre-operative mandibular plane angle showed significant correlations with post-operative changes at one year. Clinical acceptability was defined in terms of esthetics and occlusion with esthetically acceptable results occurring when both the patient and the examiner felt that there was improvement in facial esthetics and occlusion was deemed acceptable when there was a Class I canine relationship with less than 3 mm of overjet and no anterior open bite. Seventy three patients demonstrated acceptable clinical results at one year after surgery and three

patients (4%) were considered unsuccessful. The authors did state that among the three treatment failures, two patients had previously sustained bilateral condylar fractures and one patient had a bilateral nonunion of the surgical sites which required a subsequent bone graft. In all, 94% of the patients in this sample were considered to be successfully treated by the authors.

Also in 1989, Will and West (162) attempted to determine predictive factors for relapse in mandibular advancements by analyzing the radiographs of 235 patients to evaluate facial morphology, amount of advancement, amount of relapse and duration of relapse. Each patient was operated on by the same surgeon and each had inferior border wire fixation with six weeks of intermaxillary fixation. Five cephalometric radiographs were analyzed for each of the patients including a pre-orthodontic, immediate pre-operative, immediate post-operative, three weeks post-operative and six weeks post-operative film. The pre-orthodontic films were evaluated with regard to fifteen measurements chosen to determine differences in facial morphology and it was found that all of the patients had similar facial morphologies and thus it could not be evaluated as a variable with surgical relapse. Sixty one percent of the patients showed no relapse post-operatively, 28% had relapse during the first three weeks of fixation

and 11% had continued relapse through the six week fixation period. The amount of advancement, the amount of relapse and the duration of relapse were found to be significantly related to each other. Relative relapse rates and overall mean relapse was not reported.

The role of the suprahyoid musculature had long been felt to be a critical issue in mandibular advancement relapse (25, 37, 43, 44, 45, 54, 67, 73, 83, 91, 93, 106, 116, 129, 139, 158) though results of efforts to control this factor were equivocal. One need only look at various articles by Epker over the years to realize that the relative importance of this factor in mandibular advancement relapse was unknown. In 1978 he advocated use of a cervical brace or myotomy if the suprahyoids would be stretched greater than fifteen percent of their resting length (44). In 1980, he and Schendel found no difference in stability between myotomized patients and those not subjected to the procedure (129). In 1982, he indicated that a thirty percent increase in suprahyoid muscle length could be accommodated without adversely affecting the stability of the distal segment (158) though in a separate article he listed "paramandibular connective tissue tension" as one of two general etiologic factors involved in mandibular advancement relapse (43).

In an effort to clarify the role of suprahyoid muscle

tension in mandibular advancement relapse and whether or not detachment of these muscles would alleviate this relapse tendency, Ellis and Carlson in 1983 (37) evaluated stability of mandibular advancements on ten adult Rhesus monkeys, five of whom had concomitant detachment of the anterior bellies of the digastric and geniohyoid and five of whom had no myotomy. Titanium implants were placed to facilitate superimposition of serial lateral cephalograms taken during intermaxillary fixation, at fixation release and at regular intervals through ninety six weeks post-fixation. They found that the non-myotomized group exhibited a 13% relapse during the fixation period with no significant change in mandibular length following fixation release while the myotomy group showed no relapse during the fixation period and a slight increase in mandibular length post-fixation.

On the other hand, in 1982 Wessberg, Schendel and Epker (158) compared the cephalograms of eight mandibular advancement patients who were managed with simply six weeks of intermaxillary fixation to the cephalograms of eight other patients who had six weeks of intermaxillary fixation plus suprahyoid myotomy. Relapse, measured at B point, and suprahyoid stretch were calculated. The results showed no difference between the groups with the myotomy group demonstrating a mean 21.3% stretch with a 48.5% relapse and

the control group showing a mean 18.5% stretch with a 43.1% relapse.

In 1988, Reynolds, Carlson and Ellis (116) evaluated changes that occurred in the suprahyoid complex after larger mandibular advancements on twelve adult Rhesus monkeys with six monkeys fixated by intermaxillary fixation alone and the other six fixated with both intermaxillary and skeletal fixation. Once again, titanium implants and radiopaque markers were utilized for superimposition and evaluation of muscle movement. A mean relapse of 27% occurred in the group without skeletal fixation whereas no relapse was seen in the skeletally fixated group. The authors concluded that muscle stretch increases as the magnitude of mandibular advancement increases and augmentation of intermaxillary fixation with either a suprahyoid myotomy or skeletal fixation was indicated in larger advancements.

Carlson, Ellis and their colleagues again investigated the effect of suprahyoid myotomy on relapse in 1989 (25) using twenty juvenile Rhesus monkeys of which ten underwent mandibular advancement with myotomies at the insertion of the anterior digastric and geniohyoid muscles while ten underwent mandibular advancement without myotomies. Circumandibular and piriform aperture wires augmented the intraosseous and intermaxillary fixation in both groups.

The cephalometric superimpositions at release of fixation four weeks post-surgically showed the non-myotomy group experiencing a mean relapse of 13% while the myotomy group exhibited a mean increase in mandibular length over this same period. At the twelve week post-fixation cephalogram, both groups demonstrated similar magnitudes of mandibular growth.

Comparing Ellis and Carlson's findings in 1983 (37) of thirteen percent relapse in the non-myotomized group with intraosseous and intermaxillary fixation to their findings of 1989 (25) where thirteen percent relapse was found in the non-myotomized group that had their interosseous and intermaxillary fixation augmented with skeletal fixation, the role of skeletal fixation for prevention of relapse could have been considered less than definitive. In 1980 Schendel and Epker (129) found in their analysis of eighty seven mandibular advancement cases that four cases with significant open bites were successfully corrected with ramus surgery alone and noted that these cases had their fixation augmented with an average of 9.4 weeks of skeletal fixation. The authors felt that both the type and duration of fixation were important factors in the success of these cases. In 1986 Ellis and Gallo (38) looked at relapse during fixation of twenty adult mandibular advancement patients who had undergone bilateral sagittal split

osteotomies with both dental and skeletal maxillomandibular fixation for eight weeks post-surgically. Cephalometric radiographs were taken pre-surgically, immediately post-surgery and immediately prior to fixation release. Mean horizontal relapse was 8.9% of the advancements with six patients exhibiting no relapse whatsoever; relapse was not related to the amount of surgical advancement or any other variable tested. Vertical relapse was a mean superior movement at pogonion of 0.83 mm subsequent to the mean inferior surgical movement of 2.91 mm, demonstrating a reduction of anterior face height during fixation rather than the increase which was normally observed. The authors concluded that skeletal fixation assists more in providing vertical rather than horizontal support against relapse, though their findings of 8.9% horizontal relapse was excellent compared to other studies of mandibular advancements utilizing nonrigid fixation. It is interesting to speculate as to whether the small amount of horizontal relapse seen in this study was due to the beneficial effects of skeletal fixation or due to the fact that the fixation-release radiographs were taken immediately prior to fixation release and, therefore, potential condylar displacement was not included in the relapse evaluation.

These findings were further supported the following

year in a study by Mayo and Ellis (91) in which twenty four adult Rhesus monkeys underwent bilateral sagittal split osteotomies to advance the mandible, half of whom had intraosseous with intermaxillary fixation and half of whom had additional skeletal fixation. The animals were evaluated cephalometrically through six weeks post-fixation. It was found that the skeletal fixation group had no horizontal relapse and showed a reduction of anterior face height post-operatively while the group without skeletal fixation had a statistically significant degree of horizontal relapse and an increase in anterior face height.

Concurrent with studies on the influence of suprahyoid muscle tension were a number of articles describing attempts to more rigidly fixate the osteotomy sites in an effort to prevent relapse at the wound location. Beginning with Spiessl in 1974 (135), a wide variety of rigid fixation techniques have been espoused, differences between which have been based on a number of variables including the number and diameter of screws, the placement pattern of the screws, the drill type, lag or bicortical placement, pre-tapped versus self-tapping screws, intraoral versus transcutaneous placement, the potential need for plates as well as the type and configuration of plates. It is also important to understand that all types of screw fixation

are not necessarily rigid and the degree of rigidity is based on the above mentioned variables. Foley and his colleagues (46) showed that the pattern of screw placement influenced rigidity with screws placed in an inverted-L pattern being significantly more rigid than screws placed linearly. They also found no difference between bicortical and compression screws placed in the same pattern.

Van Sickels and Flanary in 1985 (148) evaluated serial cephalograms of nine mandibular advancement patients treated with sagittal split osteotomies and fixated with three transbuccal screws and either a brief period of intermaxillary fixation or none at all (mean of 1.7 days). Pre-operative, immediately post-operative, six to eight week post-operative and six to eight month post-operative cephalograms were superimposed and both horizontal and vertical measurements were taken. Mean results were reported showing minimal relapse at B point and pogonion at six weeks and subsequent forward movement of both points at six to eight months. The following year, Van Sickels and his colleagues (151) reported on results of nineteen patients who had undergone sagittal split osteotomies for mandibular advancement with the same fixation technique as was reported the year before. Radiographs were obtained pre-operatively, immediately post-operatively and six to twelve months post-operatively. The authors did not

mention the incidence of relapse nor the magnitude of advancement or relapse but they did discuss observing relapse in those cases where larger advancements were performed suggesting that the capacity of the fixation to withstand the tension of the paramandibular connective tissue was exceeded at six to seven millimeters of advancement and, thus, should be augmented with myotomies, skeletal fixation or use of larger screws.

Also in 1986, Lindorf (87) reported that seventy one of seventy six patients, twenty eight of whom were mandibular advancements, had no relapse over a twelve to thirty six month period with the use of rigid fixation consisting of three tapped screws placed in a triangular pattern. The method of evaluation was not noted.

The following year, Kirkpatrick and his colleagues (72) evaluated the cephalograms of twenty patients from three surgeons who had sagittal split advancements with three screws placed superiorly or in an inverted-L pattern. Serial cephalograms were evaluated through at least six months post-surgery. Results showed the mean horizontal relapse to be 0.42 mm or 8% of the advancement with all but one case exhibiting less than 1 mm of horizontal change, the exception having a 1.5 mm horizontal relapse.

That same year, Turvey and Hall (146) reported their early experiences with screw fixation, usually placing

three screws along the superior border. No quantitative data regarding relapse was presented but it was pointed out that three of sixty patients (five percent) needed immediate reoperation upon release of intermaxillary fixation, noting that the reoperations were among the first fifteen cases in which this fixation technique was utilized.

Van Sickels and his colleagues again published results of rigidly fixated osteotomies in 1988 (150), this time looking at fifty one patients from two oral surgery practices who had undergone mandibular advancements with sagittal split osteotomies fixated with three bicortical screws. Intermaxillary fixation ranged from zero to seven days, with a mean of 1.5 days. Their findings were essentially the same as in their 1986 study with advancements greater than 6 mm showing, on average, some relapse in the early post-operative time interval. Magnitude of advancement was the only factor that correlated with relapse in this study and it accounted for only 37.9% of the variance of the sample.

In 1989, Buckley and his colleagues (21) published a retrospective comparison of one hundred fifty patients who received rigid fixation of any type for either maxillary, mandibular or combined orthognathic procedures with one hundred twenty comparable patients who were not rigidly

fixated. Skeletal relapse was not evaluated but unanticipated occlusions immediately post-surgery and on return to the orthodontist were evaluated and found to be uncommon and essentially the same across the two groups. It should be noted that methods of evaluation were not elucidated and the descriptive statistics given were cursory at best.

The following year, Watzke and his colleagues at North Carolina (156) evaluated stability in seventy patients who had undergone sagittal split advancements. These patients were grouped by the method of their fixation, either with screws or wire, and matched on the amount of their advancement. Age, sex, concomitant genioplasty and presurgical mandibular plane angle had similar distributions between the two groups. Each case was evaluated cephalometrically by comparing pre-surgical, immediately post-surgical and one year post-surgical radiographs. Clinical results of each case were judged by occlusal evaluation and judgement of esthetics by the patient or examiner. Treatment was considered clinically successful if, at one year post-surgery, the patient had no more than 4 mm overjet, no open bite and Class I molar and canine relationships (less than one-half cusp Class II). Skeletal relapse in this study was less than 15% at the end of one year. Two thirds of the patients in both groups had

less than 2 mm change in the position of the mandible and, in the third of the patients where greater than 2 mm of change occurred, the likelihood of the mandible moving forward was the same as its moving posteriorly. Clinically, all patients met the criteria for clinical success. Four patients had 4 mm of overjet, two from each group. Each of these patients had larger advancements than the mean for the groups, between 7.2 and 10.7 mm.

Late relapse after sagittal split osteotomies can be accounted for by dental relapse and by condylar change. Both of these mechanisms can affect occlusion and facial esthetics depending on the degree of change within both of these anatomical systems and on the ability of each system to accommodate, via settling and remodelling, to these changes. Pathologic changes in condylar morphology are described under a variety of names in the literature including condylar atrophy, osteochondritis dissecans and/or avascular necrosis of the mandibular condyle, condylar resorption, osteonecrosis of the mandibular condyle, condylolysis, arthrosis deformans, progressive condylar resorption and female idiopathic condylar resorption. Certainly some degree of condylar remodelling must occur after any orthognathic surgical procedure in which the occlusion is altered. It also seems likely that extensive remodelling can occur if the position of the

condyle is altered significantly during a mandibular osteotomy and subsequently fixated rigidly in that position. Eventhough this remodelling is a normal physiologic process, some degree of occlusal relapse is likely to occur if the remodelling is extensive and if the teeth are not held together via intermaxillary fixation during the short term or an occlusal positioner in the longer term. Discussion of this process together with the degree to which it affects stability is lacking in the literature. Discussion of pathologic changes in the mandibular condyles is found in the literature, albeit in a rather confusing manner no doubt due to the variety of morphologic changes that have been described as well as the likelihood that various etiologies are involved.

In 1978, Phillips and Bell (104) published a case report of a twenty three year old woman who had a six month history of bilateral temporomandibular joint pain, a Class II dental malocclusion, mild apertognathism and mandibular retrognathia. She was treated with a six millimeter bilateral sagittal split advancement without presurgical orthodontics. During the surgical procedure the anterior border of the right ramus directly below the coronoid process sustained a fracture but it did not interfere with the successful completion of the osteotomy. The patient was fixated with bilateral circumandibular wires augmented

with wire intermaxillary fixation for eight days followed by splint removal and elastic fixation for the remainder of the five weeks of fixation. On the eighth post-operative day a panorex revealed condyles well-seated in the fossae and at the time of final fixation release there appeared to be good clinical union of the mandibular segments. Three months after surgery, the occlusion appeared stable with no clinical evidence of relapse as was the case nine months after surgery, though radiographs showed early signs of bilateral condylar atrophy. At twenty one months post-surgery, the patient was seen for follow-up and exhibited a total relapse with an anterior open bite deformity as well as both condyles appearing significantly smaller on the panoramic radiograph. Joint symptoms during the post-operative course were intermittent; the patient had bilateral temporomandibular joint pain on awakening two weeks after surgery which was relieved with 5 mg of diazepam at bedtime, she reported occasional "popping noise" in the right joint three months after surgery and eight months after surgery she complained of right side joint pain and an episode of a temporary "locked open" jaw, all of which resolved with conservative therapy including rest, occlusal disengagement and muscle relaxants. At her nine month post-operative follow-up she was symptom free. The patient was tested for rheumatoid factor prior to her

surgery in 1970 and had complete studies for rheumatoid arthritis after her surgical relapse; both were negative. In 1977 she underwent a Le Fort I osteotomy and her occlusion was stable at the six-month follow-up. The authors hypothesized that the condylar atrophy seen in this case could have been due to either vascular ischemia resulting in aseptic necrosis or pressure resorption due to the mechanical influence of muscle and soft tissue pressure, though either explanation seemed unlikely.

In 1980, Worms and his colleagues (170) discussed a number of the factors that they felt led to a less than optimal orthognathic treatment result, one of these factors being condylar resorption. They presented the case of a young woman who had undergone a mandibular advancement procedure to correct a severe mandibular retrognathia. Serial radiographs which were able to be superimposed on bilateral vitallium mesh plates secured with four screws demonstrated that condylar resorption was a "major adjustment area" of the skeletal relapse observed in this case. Unfortunately, details of the preoperative occlusion, reproductions of the panoramic and tomographic radiographs and/or details of the temporal course of the relapse were not included so independent assessment of the relapse as condylar resorption as opposed to a more typical relapse sequelae of a Class II with (probable)

apertognathia was not possible.

Huang and Ross in 1982 (64) evaluated the radiographic records of twenty two children who had undergone surgical correction for mandibular retrognathia at one institution in Toronto. Among a variety of other findings, the authors reported that five of the cases demonstrated condylar resorption from fixation release to the last available post-surgical record (minimum of two years and mean of four years). One of these cases was a girl with juvenile rheumatoid arthritis but the other four cases were of two boys, ages 14.8 and 15.6, and two girls, ages 13.4 and 15.0, who did not have any diagnosed craniofacial anomaly or connective tissue pathology. The authors felt that mandibular relapse, much of it due to condylar resorption, was primarily seen in those patients who had larger mandibular advancements (range 11 to 24 mm, mean of 16.4 mm compared to an overall mean of 10.9 mm); no condylar resorption was seen in patients who had advancements less than or equal to 12 mm.

In 1986, Kent and his colleagues at LSU (69) published a description of the temporomandibular manifestations of rheumatoid disease and other arthropathies. Included in this description were eight patients who had been seen over twelve years and had exhibited significant condylar destruction of unknown etiology. All were females in the

second and third decades of life, histories and laboratory studies were negative for any rheumatoid disease, most had Class II malocclusions prior to the condylar resorption process and seven of the eight gave "a history of long orthodontic treatment but no surgery." The authors grouped these patients into their classification system as Type IV or idiopathic condylar resorption patients and described signs and symptoms that included a developing open bite and worsening retrognathic profile, variable degrees of temporomandibular joint pain and dysfunction and a radiographically reduced joint space with "small, flattened, shortened condyles" that were not spiked as was commonly seen with rheumatoid arthritis patients. The authors did state that three of the eight patients had undergone total joint reconstruction, three had orthognathic surgery with maxillary superior repositioning and mandibular advancement and two were successfully treated with anti-inflammatory medications and splints to "produce relief of pain and condylar remodelling." Two of the three patients treated with orthognathic surgery experienced long-term relapse from continued condylar resorption.

In 1989, Schellhas and co-workers (127) described the magnetic resonance images of forty five mandibular condyles from forty patients who they felt exhibited radiologic

changes indicative of either osteochondritis dissecans or avascular necrosis. Five patients who, according to the authors, exhibited avascular necrosis unilaterally or bilaterally had undergone orthognathic surgery, "including bilateral sagittal split mandibular osteotomies, followed by rigid intermaxillary fixation" within twenty four months of the magnetic resonance evaluations of their temporomandibular joints. The authors felt that "many cases of acquired malocclusion, facial deformity and condylar degeneration may be the consequence of avascular necrosis" and that it may occur as a complication of orthognathic surgery.

In 1990, Kerstens and his colleagues (71) described radiographic condylar atrophy in twelve of two hundred six patients who had undergone orthognathic surgery at the same institution. Eleven of the patients had undergone bimaxillary surgery and one patient had a bilateral sagittal split advancement alone; each of the patients was placed into wire intermaxillary fixation for four to six weeks post-operatively. All twelve of the patients exhibited mandibular retrognathia with high mandibular plane angles pre-surgically. No information was given as to the age and gender of the patients. The authors did note that nine patients had unilateral condylar bone loss while three exhibited bilateral changes and that the

greatest amount of bone loss was located on the anterior condylar surface. Clinically, eight patients had pre-operative temporomandibular joint sounds with or without pain and two of these patients were without any joint symptoms post-surgically. Two patients were totally asymptomatic throughout the pre-operative to post-operative course. Tracings of the involved condyles appeared to demonstrate significant "remodelling" with areas of both resorption and deposition; no condyle showed gross diminution in size or obliteration of condylar form. Finally, the authors did not correlate the visible condylar "atrophy" with any post-surgical relapse, either skeletal or dental.

Also in 1990, Arnett and Tamborello (2) described ten patients they identified as having progressive mandibular retrusion due to idiopathic condylar resorption. All of the patients were female between the ages of twelve and twenty seven years (mean = twenty years) with a duration of active condylar change of two to seven years (mean = four years). All were evaluated to rule out anterior condylar displacement which returned to a normal position slowly during treatment, disproportionate growth, surgical relapse at osteotomy sites, orthodontic relapse and systemic arthritis. Seven of the ten patients had previous orthodontic treatment a total of fifteen times and six of

the orthodontic patients had orthognathic surgery, five of whom were not recognized pre-surgically to have active condylar resorption and continued to have B point regression after surgery in spite of good condylar position and a Class I occlusion at the time of surgery. The one orthodontic patient who had a stable post-surgical course had undergone long-term splint stabilization to document cessation of the progressive mandibular retrusion prior to surgical correction of her skeletal discrepancy. Three of the patients had never received orthodontic treatment and their joint symptoms and progressive Class II malocclusions began, in one case, subsequent to the extraction of third molars and in another case subsequent to a blow to the chin with no concomitant mandibular fracture; the third case had no identifiable initiating incident. All three patients underwent orthognathic surgery after splinting and courses of anti-inflammatory medication. Two patients have remained stable and one has undergone continued mandibular regression.

The authors went on to discuss late surgical relapse which they felt to be a multifactorial process and which, when not due to systemic arthritis, orthodontic relapse or loss of the dental compensations that can occur during osteotomy healing, was associated with loading of the temporomandibular joints and subsequent loss of disk space,

disk thickness or condylar height. They discussed numerous joint-loading mechanisms, including intraoperative loading of the condyles by the surgeon, intraoperative loading by the surgical hardware during fixation and postoperative muscle loading, i.e., clenching and bruxing. Female condylar resorption was viewed as an extreme physiologic reaction to condylar loading in predisposed patients as opposed to the more typical reaction of condylar remodelling.

Moore and his colleagues reported in 1991 (95) on five cases of condylar resorption out of 421 patients to have received sagittal split osteotomies, Le Fort I osteotomies or a combination of the two. All five patients were female between the ages of eighteen and twenty five, all had bilateral sagittal split osteotomies and two also had concomitant Le Fort I osteotomies, all had Champy miniplate fixation and three had concomitant wire intermaxillary fixation for six weeks. Radiographic signs of condylar resorption were evident six to seventeen months post-surgery with clinical signs of relapse and temporomandibular joint symptoms preceding the radiographic signs. Three patients underwent subsequent osteotomies twenty to thirty months after the first procedure and two of these patients have remained stable with one patient having experienced renewed condylar resorption. The

authors noted that all five patients had high mandibular plane angles (forty degrees or higher) and they all had low posterior face height to anterior face height ratios (66% or less).

In 1992, Link and Nickerson (88) evaluated the temporomandibular joints of thirty nine patients pre-orthognathic surgery and post-surgery with regard to joint noise and interincisal opening as well as condylar morphology as depicted on transpharyngeal radiographs. The patients were all from one surgical practice and had Class I open bites, a Class II subdivision malocclusion or a Class II malocclusion with or without an open bite. Thirty five of these patients had bilateral inferior space arthrograms performed pre-operatively to determine disc position and the other four were assumed to have anteriorly displaced discs based upon their bilateral condylar deformities. All but two patients had mandibular procedures performed, thirty one having bilateral sagittal split advancements, five having vertical ramus osteotomies and one having a unilateral sagittal split osteotomy along with a unilateral vertical ramus osteotomy. The authors found a 97% "incidence" of internal derangement in their patient sample though they felt that some "selection bias based on chance or referral pattern" may have been involved, apparently minimizing the fact that one Class II

malocclusion patient was excluded because he had not had an arthrogram and had normal condylar morphology. Logic aside, the authors felt that the high degree of association of internal derangement with mandibular deficiency may suggest a causative role and that disc displacement either prevents skeletal development or actively causes a "reversal of skeletal development" at the site of the condyles. Fifteen of the thirty patients that were followed for greater than twelve months developed "new or active arthrosis" post-surgically and five of these patients exhibited occlusal relapse of 2 mm or more. It should be noted that four patients with 2 mm or greater of mandibular relapse did not have an "arthrotic event" post-surgically and the authors, in fact, stated that they could not prove that the arthroses caused the relapses.

In 1993, Cassidy and his colleagues (26), while comparing Class II "borderline" subgroups treated orthodontically or surgically, found three of the twenty six orthognathic surgery patients who appeared to have undergone "extensive condylar resorption" post-operatively. The exact follow-up time period of these three patients was not stated, though it had to have been at least forty eight months post-surgery in accordance with the protocol of the study. The amount of relapse of these three patients was not stated though the authors did note that the surgical

relapse of all twenty six patients averaged 25% to 30% of the mandibular advancement and that the twenty three patients who did not experience "extensive condylar resorption" lost "an average of about 13%". Neither the gender nor age of the three patients was mentioned, nor were any details given as to the temporal aspects of the relapse. No descriptions of the extensively resorbed condyles were given nor were details as to what diagnostic tools, except for lateral cephalograms, were used to make the diagnosis of extensive condylar resorption. Finally, no descriptions were given about the pre-surgical, immediately post-surgical nor long-term follow up occlusions of these three patients. The authors did, however, emphasize that because 11.5% of their surgical sample of twenty six had undergone "extensive relapse, apparently as a result of condylar resorption...from the standpoint of the probabilities and utilities of formal decision theory...on average, orthodontic treatment is appropriate for the adult patient with Class II malocclusion who can be treated either way."

The following year Merkx and Van Damme (94) reported that eight patients out of 329 treated between 1981 and 1991 by unilateral or bilateral sagittal split osteotomies for correction of skeletal Class II, Class III or laterognathic malocclusions underwent bilateral or

unilateral condylar resorption during their post-operative course. Each of the surgeries was fixated with superior border wires and six weeks of intermaxillary fixation without an occlusal splint. All eight patients were female with an average age of 23.3 years (range of 20.1 to 26.11 years), an average preoperative mandibular plane angle of 38.5 degrees (range of 32 to 53 degrees) and they were all advanced an average of 7.3 mm (range of 5 to 10 mm) with a concomitant counterclockwise rotation during surgery in six of the cases. Seven patients experienced bilateral condylar resorption while one laterognathic patient underwent unilateral condylar resorption on the advancement side. The diagnosis of condylar resorption was based on subjective complaints of decreased masticatory function, profile change and temporomandibular joint pain as well as physical findings of occlusal change including an increased overjet and decreased overbite plus diminished condylar volume and contour irregularities on panoramic radiographs. The authors noted that the first subjective signs of relapse were seen an average of 6.7 months (range of .75 to 19 months) and stabilized an average of 27 months (range of 12 to 38 months) post-surgery. Four patients were reoperated due to functional and esthetic problems with three undergoing bilateral sagittal split advancements combined with Le Fort I osteotomies and one patient

undergoing a Le Fort I alone. The three sagittal split osteotomy patients began relapsing within 3.5 months of the surgery and had radiographic condylar resorption visible at one year post-surgery. One of these patients developed such a severe open bite that a mandibular segmental osteotomy was performed three years after the second surgery to stabilize the occlusion. The patient that was treated with a Le Fort I alone for the second procedure also relapsed significantly during the following year.

That same year, Bouwman and his colleagues (19) radiographically evaluated the condyles of 1025 patients orthognathically treated at the Free University Hospital in Amsterdam from 1983 to 1992. All Class III patients were treated with vertical ramus osteotomies and fixated with four to six weeks of intermaxillary fixation. The Class II patients underwent bilateral sagittal split osteotomies with those treated from January 1983 to August 1988 being fixated with superior border wires and four to six weeks of intermaxillary fixation while those treated from August 1988 to January 1992 were fixated with three superior border screws per side and intermaxillary fixation which was removed directly after surgery. Maxillary surgery was concomitantly done to prevent counterclockwise rotational movements of the mandible during advancements. The one year post-operative radiographs showed a change in shape

and volume of the condyles in thirty two patients, 3% of those evaluated. All thirty two patients were described as having high angle mandibular deficiency prior to surgical correction and all but eight of the patients were treated with bimaxillary procedures. The entire group of high angle Class II patients were subsequently analyzed with regard to fixation type, the results showing condylar resorption in 24 of 91 patients (26.4%) who had intraosseous fixation and 8 of 67 patients (11.9%) who had rigid fixation. The authors did not describe the ages of the condylar resorption patients and it was unclear as to whether all those affected were female in this cohort. The authors did note that fourteen patients had demonstrated signs of osteoarthritic changes of the condyles on their preoperative radiographs. They also noted that it was difficult to quantify major volume changes of the condylar head and that investigators were not blinded as to the method of fixation when evaluations were made. Nonetheless, the authors advocated informing high angle, mandibular deficient females of the possibility of condylar resorption as a potential sequelae to orthognathic surgery.

Again that same year, Crawford in Seattle with Stoelinga and his colleagues in Arnhem (29) presented the results of reoperation on seven patients who had progressive condylar resorption as a sequelae to their

original orthognathic surgery, including five patients who had been reported in the literature earlier (95). The authors defined progressive condylar resorption as a change in condylar morphology from normal to fingershaped as well as a decrease in posterior face height. The seven patients presented were all female between the ages of eighteen and thirty and all experienced clinically significant, late relapse due to progressive condylar resorption. They were all treated with occlusal splint therapy during the period of active resorption with six patients exhibiting skeletal and occlusal stability for at least twelve months prior to reoperation while the remaining patient had been stable for six months. Five of the seven patients had further clinically significant condylar resorption after their second surgeries and one of these patients had yet a third osteotomy with subsequent condylar resorption. Also of note, three of the patients underwent temporomandibular joint surgery due to anteriorly displaced, non-reducing discs; two of these patients had disc replacement and one had surgical disc repositioning. Subsequently, two patients had stable post-operative courses while one had continued condylar resorption. The authors concluded that progressive condylar resorption is not a temporally isolated event and that more information is needed on its etiology and course in order to more effectively deal with

its effects.

In another article out of Arnhem in 1994, Scheerlinck and his colleagues (126) evaluated one hundred twenty four patients treated with bilateral sagittal split osteotomies for mandibular advancement. No other surgeries were concomitantly performed. Fixation was with Champy plates and four monocortical screws augmented with three days of continuous, tight elastic intermaxillary fixation. Cephalometric and panoramic radiographs were obtained for each patient pre-operatively, within three days post-operatively, and at three months, six months, one year and at the last post-operative visit, at least twenty four months post-surgery. Advancement at B point averaged 5.85 mm (range of 1.5 mm to 13.5 mm) and skeletal relapse averaged 0.52 mm or 8.9% of the advancement (range of 1.75 mm anterior movement to 9.5 mm posterior movement). The authors pointed out, however, that 93 of the 103 patients had "relapse" of -0.5 mm to +0.5 mm. Eight patients exhibited radiographic signs of significant condylar resorption with four patients exhibiting "complete disappearance of the condylar contour" while the other four patients had partial condylar resorption; six of the patients had unilateral resorption and two of the patients showed bilateral resorption. These eight patients were found to have had B point relapse of 35% to 120% and seven

of the eight patients had pre-existing temporomandibular joint dysfunction. Interestingly, two patients had high mandibular plane angles (43 and 47 degrees to Frankfort horizontal), one patient had a low mandibular plane angle (26 degrees) and the remaining five patients had mandibular plane angles ranging from 30 to 36 degrees. Also of note, there appeared to be a relationship between magnitude of advancement and condylar resorption with the risk for condylar resorption being 5.2 times higher in patients having advancements between 5 mm and 10 mm and twenty times greater for those with a larger than 10 mm advancement than for those with less than a 5 mm advancement.

Harkening back to the work of Schellhas in 1989 (127) in which osteochondritis dissecans or avascular necrosis was suggested as a sequelae to orthognathic surgery, Chuong and his colleagues in 1995 (27) discussed the diagnosis and treatment of condylar osteonecrosis as a possible cause of facial skeletal instability, including that seen long-term following orthognathic surgery. The authors, in correlating the diagnosis with radiographic findings on T1-weighted and T2-weighted magnetic resonance scans of the condyles as well as histologic criteria, suggested a prevalence of condylar osteonecrosis in the range of one to four percent within a "mixed patient group in a surgical practice".

Mandibular Set-Back

Contemporary surgical treatment for mandibular prognathism primarily utilizes either the sagittal split ramus osteotomy or an intraoral vertical ramus osteotomy. The intraoral vertical ramus osteotomy was first described by Winstanley in 1968 (164) and modified two years later by Hebert, Kent and Hinds (59) and modified again by Hall and McKenna in 1987 (57). Generally speaking, the vertical ramus osteotomy is a technically simpler and usually shorter procedure with less chance of damage to the inferior alveolar nerve while application of rigid internal fixation is easier with the sagittal split osteotomy (55).

Stability of the surgical correction of mandibular prognathism is thought to be dependant upon many of the same factors that influence the stability of mandibular advancement surgery including the magnitude of the surgical set-back (48, 74, 102, 113), proximal segment control involving both the degree of condylar displacement during surgery and proximal segment rotation (48, 56, 66, 76, 81, 102, 120, 154, 165) as well as the type and duration of fixation (66, 76, 78, 99, 123, 144). Growth, or more accurately, a lack thereof, is also a key factor in the long-term success of mandibular set-back surgery while condylar "resorption" appears to play a very limited role

in stability of this type of orthognathic movement.

The early literature on relapse of mandibular set-back surgery did not confine itself to relapse subsequent to one specific type of osteotomy but rather to any and all surgical procedures used in the treatment of mandibular prognathism. In 1974, Reitzik (114) radiographically evaluated fifty consecutive adult cases of surgically corrected mandibular prognathism. Details of the radiographic evaluation were not given though radiographs were taken prior to surgery, immediately after surgery and at least one year after fixation release. This series of cases involved the use of a variety of surgical techniques, both intra-oral and extra-oral, including horizontal ramus osteotomy, subcondylar osteotomy, vertical subsigmoid osteotomy, Angle ostectomy and a Dal Pont modified sagittal split osteotomy; no comparisons were made of the results from each type of surgery. Measurement of mandibular change was made in degrees rather than millimeters, thus absolute relapse was not evaluated. Nonetheless, the author found that the SNB angle was decreased post-surgically an average of six degrees and that, after one year, half of the cases "relapsed forward...up to four degrees...without in any way prejudicing the clinical result." Only one case relapsed into a Class III incisor relationship and three cases relapsed to an edge-to-edge

relationship. Three quarters of the cases demonstrated a retroclination of the upper incisors of up to eight degrees and almost every case demonstrated proclination of the lower incisors of up to twenty one degrees (mean of six degrees). The most interesting finding was that even though the mandibular plane angle was high in this cohort (mean SNMP of 39 degrees with a range of 24 to 57 degrees), 90% had a post-operative increase in the mandibular plane angle of an average of six degrees. The author mentioned that an "open-bite relapse of varying degree" was seen but not quantitatively described.

Six years later, Reitzik further elucidated the findings on this same cohort of patients (113). In the later article it was pointed out that none of the fifty patients had undergone pre-operative nor, within one year, post-operative orthodontics and the later article again did not include the methods used in the "detailed cephalometric assessment" that was applied in each of the cases. Comparisons were made between the types of mandibular set-back surgeries performed and a number of linear measurements were made. As previously stated, 37 cases demonstrated retroclination of the maxillary incisors of up to eight degrees. The author pointed out that in every case of retroclination there was no contact post-operatively between the maxillary and mandibular incisors

in centric occlusion while in every case of maxillary incisor proclination there was complete contact post-operatively. It is also noteworthy that eight of the eleven cases showing some degree of maxillary incisor proclination were surgerized with sagittal split osteotomies. In fact, the mean angular change in the maxillary incisors to SN for those treated with sagittal split set-backs was zero degrees; all other procedures had negative mean angular changes ranging from -1.8 degrees in the Angle ostectomy to -3.33 degrees in the vertical subsigmoid osteotomy. Regarding "horizontal" mandibular relapse (again, determined by change in SNB), the amount of long-term change was small, only 1.07 degrees though the largest percentage relapse was seen in the sagittal split osteotomy group with 20.9% relapse in SNB. The author pointed out that, in general, the greater the magnitude of set-back, the greater the relapse, though the range was broad. Interestingly, from the 1974 report to the 1980 report the number of Class III incisor relationships increased from one to two cases and the number of edge-to-edge incisor relationships increased from three to eight cases. With regard to the mandibular plane angle, the mean SNMP for this group pre-operatively was 38.7 degrees with women having a more obtuse angle than men (means of 40.05 degrees and 37.64 degrees respectively). At surgery, this

angle increased a mean 2.7 degrees. In the long-term post-operative radiographs there was a further mean increase of 3.62 degrees. Posterior facial height generally decreased considerably with an average 2.96 mm decrease at surgery and a further 3.2 mm decrease over the long-term for a substantial 6.16 mm mean decrease in posterior facial height. Finally, though it was not quantified, the author noted that "typical open bite relapses (were) seen with some frequency during this study...". In reworking the data that was first reported in 1974, Reitzik clearly demonstrated that, though the majority of cases exhibited clinical "success" both dentally and skeletally in the correction of the anteroposterior problem, significant negative sequelae occurred in the vertical plane.

Though it was previously discussed in the review of the literature of mandibular advancement surgery, the article by Isaacson and his colleagues in 1978 (66) which evaluated the movement of both the proximal and distal segments after mandibular ramus surgeries deserves consideration with regard to mandibular set-back surgery. Eighteen prognathic patients were surgically treated with mandibular osteotomies, sixteen with extraoral bilateral subcondylar vertical osteotomies and two with Dal Pont modified sagittal split osteotomies. Serial cephalometric and tomographic radiographs showed that, at the time of

surgery, the proximal segment rotated clockwise a mean 5.6 degrees relative to Frankfort horizontal while the condyle was displaced inferiorly a mean 1.6 mm and anteriorly 2.1 mm. Every case showed a tendency to return toward its presurgical position between the time of surgery and final records, with the proximal segment rotating counterclockwise a mean 6.8 degrees and the condyle moving superiorly approximately half of the mean inferior surgical displacement and posteriorly approximately 80% of the mean anterior surgical displacement. The distal segment was surgically moved, on average, 10.3 mm posteriorly and at final records all cases had relapsed anteriorly a mean 1.4 mm while posterior face height was increased during surgery a mean 5.9 mm (including the splint) and decreased over the long term an average of 4.2 mm. The authors emphasized that without intraosseous fixation, the occlusion remains stable during intermaxillary fixation while the proximal segments return to an unstrained physiologic position.

The first report of relapse in sagittal split set-backs was in 1965 when Egyedi (36) reported on his method of evaluating relapse in fourteen prognathic patients who had undergone sagittal split set-backs, none of whom had pre-operative or post-operative orthodontics. Lateral cephalometric films were taken during fixation, usually within a week of the surgery and at least one year post-

surgery. Due to a change in radiographic equipment during the study period, validity of the measurements could be questioned though general trends are worth noting. Eight of the fourteen patients showed relapse at pogonion with an overall mean relapse of 17.5 percent. In the long-term cephalograms, four people showed an increase in anterior face height while two people showed a decrease; no patient had a frank open bite post-operatively.

In 1978, Pepersack and Chause (100) evaluated sixty seven cases of mandibular prognathism that had been treated five or more years previously with sagittal split set-back surgery via clinical, radiologic and model examination. The authors defined relapse as forward movement of the lower incisors greater than 1.5 mm as evaluated on the models and subsequently radiographically compared the relapsing cases to the non-relapsing cases. The mean correction in this cohort was 6.2 mm and relapse occurred in nine (8%) of the cases, six of whom had anterior crossbite or an edge-to-edge incisal relationship, with 73% having a good to excellent long-term occlusion and 9% having poor occlusion without relapse. Cephalometrically, surgery increased the mandibular plane angle a mean 2.3 degrees with the non-relapsing cases opening up slightly more (2.5 degrees) than the relapsing cases (1.6 degrees). Over the long term, the mandibular plane angle increased

marginally in the non-relapsing group (0.4 degrees) and more substantially (2.0 degrees) in the relapse group. As one would expect, anterior face height increased an average 3.4 mm in the relapse group but did not change over the long-term in the non-relapse group. There was minimal long-term change in SNB for either group. Finally, clinical examination of patient profiles found that there was no relationship between the degree of observed occlusal relapse and the final profile.

In 1981, MacIntosh (90) reviewed his thirteen year experience with the sagittal split osteotomy and included one hundred thirty two prognathic patients who had undergone set-back procedures, the majority of whom had circumandibular wire fixation as well as intermaxillary fixation. Relapse was evaluated on both models and superimposed pre-surgical and at least six months post-surgical cephalographs. Models were evaluated post-fixation and again at one year or more post-surgery; from fixation to the long term, approximately 20% of the patients exhibited up to 1 mm of anteroposterior and/or vertical change in their occlusion, 10% exhibited 1 mm to 2.5 mm change and approximately 1.5% had more than 2.5 mm change in their occlusion. Radiographic relapse of up to 1 mm change in pogonion was seen in 11% of the cases while 2.5% showed a change from 1 to 4 mm.

The use of the sagittal split osteotomy for correction of mandibular prognathism was again evaluated in 1986 by Kobayashi and his colleagues in Nigata and Ojiya City (74). Forty-four cases, eight of whom had concomitant open bites, were evaluated cephalometrically prior to surgery, one week, six months and at least one year after surgery; occlusal evaluation was also done on pre-operative, predictive and final (at least one year post-surgery) casts. All patients had undergone pre-operative and post-operative orthodontics, all had undergone sagittal split set-backs with intraosseous wiring and approximately fifty days of intermaxillary fixation followed by chin cup night-wear for six months. Cephalometrically, the mandible was retruded an average of 8.4 mm at B point and pogonion with 3.0 mm superior movement at menton. B point relapse occurred in twenty nine patients with a mean 0.6 mm of anterior movement; seven patients exhibited B point relapse of 2 mm or more. Overall mean vertical movement was not statistically significant. Overjet averaged -5.0 mm before surgery, 2.5 mm after surgery and averaged 2.1 mm in the final casts with eight patients exhibiting more than 1.5 mm of overjet decrease from surgery to the final casts. Overbite averaged 0.6 mm prior to surgery, 2.6 mm at surgery and 2.0 mm in the final casts. One patient developed a 0.8 mm open bite and four patients had end-to-

end occlusion in the final models. Magnitude of relapse was significantly proportional to the magnitude of horizontal surgical correction but there was no correlation between post-operative vertical change and the surgical vertical correction. There was a weak correlation between relapse and a rotation or lateral movement of the mandible during surgery.

The following year, Komori and his colleagues in Tokyo (77) evaluated relapse of sagittal split osteotomies in seventeen mandibular prognathic patients without open bites. All of the patients had four to five weeks of intermaxillary fixation but skeletal fixation with bilateral suspension and circumandibular wires was also placed in ten of the patients. Serial cephalograms were taken at initial exam, immediately pre-surgery, a few days after surgery and immediately before fixation release. During fixation, the group with skeletal fixation showed a 0.1 mm upward and 1.0 mm backward movement at pogonion while the control group had a 1.9 mm downward and 3.0 mm backward movement at pogonion. Gonion moved forward and upward in both groups. Mandibular plane angle differences were significant between the groups with the skeletal fixation group increasing 2.3 degrees and the control group increasing 4.9 degrees. Upper incisor axial inclination showed expected compensatory changes with a decrease in

inclination of 6.1 degrees in the control group and a decrease of 2.3 degrees in the skeletal fixation group while extrusion occurred in both groups with 1.9 mm of extrusion observed in the control group and 0.5 mm in the skeletal fixation group. The occlusal plane rotated counterclockwise in both groups with the fulcrum being located at the distal cusp of the lower first molars in the control group and at the canine in the skeletal fixation group.

In 1989, these same authors (76) sought to explain the causes of the skeletal relapse that had been seen two years earlier, specifically as to whether or not position and/or angulation of the proximal segment was responsible for the post-surgical changes. Fifteen patients, including the ten previously described, were cephalometrically evaluated for relapse after undergoing sagittal split osteotomies followed by four to five weeks of intermaxillary fixation augmented with skeletal fixation. The authors found that proximal segment rotation was a significant factor in distal segment relapse during fixation while the magnitude of the set-back and rotational movement of the distal segment at surgery did not correlate with relapse.

The vertical ramus osteotomy was originally described by Caldwell and Lettermann in 1954 (24) and was an extraoral procedure in which the osteotomy cut began at the

sigmoid notch and ended anterior to the angle of the mandible. Oblique ramus osteotomies, popular during the mid to late 1960s and early 1970s extended from the sigmoid notch to anywhere along the posterior aspect of the ramus and included condylotomies, medium-extension osteotomies and ramal osteotomies in which the caudal aspect of the cut ended at the gonial angle. Extraoral vertical and oblique ramus osteotomies remained very popular in Europe through the first half of the 1980s even after Winstanley's description of an intraoral approach (164) made the intraoral vertical ramus osteotomy de rigueur in the United States by the late 1970s. This has important ramifications when reviewing the literature on relapse of the intraoral vertical ramus osteotomy since most reported relapse studies of mandibular set-back osteotomies, not including sagittal split set-backs, were done in Europe in the 1970s and 1980s on relapse of extraoral vertical or oblique ramus osteotomies. Comparison of the relapse observed after extraoral vertical ramus osteotomies to that seen after intraoral vertical ramus osteotomies was done in 1988 by Tornes and Wisth in Norway (144), who cephalometrically analyzed the positional changes of the mandible and the incisors following mandibular set-back surgery on 80 patients, none of whom had an open bite or laterognathia and all of whom had pre-operative orthodontia. Forty

patients had received an intraoral vertical ramus osteotomy while the other forty had received an extraoral vertical ramus osteotomy; no intraosseous wiring was used and patients were placed into intermaxillary fixation for six weeks followed by one week of elastic fixation. Fifteen patients in the extraoral osteotomy group had concomitant skeletal fixation consisting of circumandibular and piriform aperture wiring as did seventeen of the intraoral osteotomy patients. Serial cephalographs were taken pre-operatively, six weeks post-operatively and again six months post-operatively. The results of the analysis found that both groups exhibited an increase in mandibular plane angle, a decrease in posterior face height and extrusion of the maxillary and mandibular incisors. There were no intergroup differences except that the decrease in posterior face height was significantly greater in the extraoral osteotomy group. The mean surgical decrease in overjet was sustained through the six month post-operative period and no mention was made of any dental relapse to anterior crossbite or edge-to-edge occlusion. Skeletal relapse of the mandible was 13.4% in the intraoral osteotomy group and 9.7% in the extraoral osteotomy group but it is important to note that these were evaluated as angular changes in SNB. In evaluating the differences between the skeletally fixated group and the group with

intermaxillary fixation alone it was found that, over the entire observation period, the group without skeletal fixation exhibited more increased anterior face height, retrusion of the maxillary incisors and extrusion of the mandibular incisors than the group with skeletal fixation.

Since extraoral and intraoral ramus osteotomies appear to have similar patterns and degrees of relapse, it is pertinent to review two articles out of Sweden from the mid-1980s by Rosenquist (121, 122) in which titanium implants were surgically placed in both the maxillas and mandibles of fourteen extraoral ramus osteotomy patients apical to and between the roots of the central incisors and apical to the roots of the first molars. The patients subsequently underwent extraoral oblique sliding osteotomies to correct mandibular prognathism and were placed into intermaxillary fixation for eight weeks. In the first article (122), stereo radiographs were obtained before surgery, two to three days after surgery and immediately before removal of the intermaxillary fixation. During surgery fourteen patients were retropositioned an average of 5.4 mm with eight of the mandibles being rotated in a counterclockwise direction and six rotated clockwise. During intermaxillary fixation, the mandible displaced posteriorly a mean 1.6 mm and rotated a highly significant mean of 4.5 degrees clockwise. Also, both maxillary and

mandibular incisors extruded during fixation with the maxillary incisors extruding an average of 2.1 mm and the mandibular incisors extruding a mean 1.6 mm. No significant correlation was found between the magnitude of surgical set-back and amount of post-operative displacement. The second article by Rosenquist and his colleagues (121) dealt with mandibular displacement after intermaxillary fixation removal in which comparisons were made of stereo radiographs taken immediately before and after fixation and again at three months, six months, one year and two years post-surgery. A continuous anterior relapse was observed over the entire period of evaluation while a vertical translation of 0.4 mm occurred at the three month observational period but did not continue beyond this point. A small counterclockwise rotation of the mandible also occurred over the evaluation period and a proclination of the maxillary and mandibular incisors occurred during the first post-operative year.

As has been previously noted, the intraoral approach of the vertical ramus osteotomy originally gained widespread popularity in the United States so it is understandable that the earliest reports on this procedure are found in the American literature. Unfortunately, very few follow-up studies have been reported anywhere in the professional literature.

In 1975, Hall and his colleagues in Nashville (56) reported on the treatment results of forty two patients who had received intraoral vertical subcondylar osteotomies. They noted from panoramic and subsequent tomographic radiographs that the condyles from a number of patients exhibited an anteroinferior displacement post-operatively with one patient exhibiting an anterior dislocation. Occlusal relapse was seen in three patients, though no attempt was made to correlate this to skeletal relapse though one case was thought to be due to subsequent growth. Six patients exhibited a small anterior open bite immediately after intermaxillary fixation release which the authors attributed to condylar sag.

In 1987, Hall and his colleagues published a follow-up article (57) in which the surgical complications seen in eighty nine patients who had been treated with intraoral vertical ramus osteotomies between 1978 and 1985 were discussed. Of note, no patients exhibited an anterior open bite upon fixation release eight weeks post-surgery. The authors attributed this change from that seen in 1975 to an alteration in technique which aided in condylar seating during intermaxillary fixation and an increased duration of intermaxillary fixation. No sagittal or vertical relapse was detected but this was a clinical determination since "variations in cephalometric technique prevented more

careful analysis of possible minor skeletal relapse."

Proffit and his colleagues in Chapel Hill evaluated patients treated with mandibular surgery for Class III malocclusion at their institution during the 1980s and on whom no other concomitant orthognathic procedure, except for genioplasty, was done. In 1991, they published their results (107) comparing the stability of the intraoral vertical ramus osteotomy, the bilateral sagittal split osteotomy with wire osteosynthesis and intermaxillary fixation and the bilateral sagittal split osteotomy with rigid internal fixation via bone screws. The patients were evaluated cephalometrically prior to surgery, immediately after surgery and at least one year post-surgery. Statistically significant differences were found between the groups with regard to horizontal stability with both sagittal split osteotomy groups exhibiting a mean forward relapse at one year and essentially no mean change in the horizontal position of the mandible in the vertical ramus osteotomy group. There was, however, a very broad range of relapse within all of the groups. Within the vertical ramus osteotomy group, at one year, 22% of the patients exhibited a posterior movement at pogonion of 2 to 4 mm while 10% of the patients exhibited greater than 4 mm of posterior movement. Anterior movement at pogonion of 2 to 4 mm was seen in 10% of the patients and more than 4 mm of

anterior relapse was seen in 5% of the vertical ramus osteotomy patients. On the other hand, there were no patients in either sagittal split group who exhibited a posterior movement of pogonion at long-term follow-up. Within the wire osteosynthesis group, 38% of the patients had a 2 to 4 mm anterior movement at pogonion at one year while 24% had greater than 4 mm of relapse; within the rigid fixation group, pogonion moved anteriorly 2 to 4 mm in 55% of the patients and moved greater than 4 mm anteriorly in 27% of the patients. Vertically, there was no statistically significant difference between the groups although both the vertical ramus osteotomy group and the sagittal split with wire fixation group had a large percentage of patients exhibiting a downward vertical movement at gonion of 2 mm or greater while the rigidly-fixated sagittal split patients exhibited a broad range of post-surgical vertical movements with approximately 30% demonstrating a downward vertical movement at gonion over the long-term and approximately 20% exhibiting an upward vertical movement at gonion of 2 mm or greater. The authors felt that anterior relapse post-surgery was due to either a repositioning of the mandible by muscle pull as function resumed or by an adjustment in the condyle-fossa relationship following retropositioning during surgery. No mention was made of occlusal change during the evaluation

period for this patient sample.

As with sagittal split advancement surgery, rigid fixation was utilized with sagittal split set-backs in an effort to better stabilize the osteotomy site. A study by Kundert and Hadjianghelou in 1980 (81) evaluated condylar movements during sagittal split osteotomies. Nineteen prognathic patients underwent sagittal split retropositioning of the mandible as described by Obwegeser; intermaxillary fixation augmented with circumferential wiring was done on seven of the cases while the remaining twelve cases had screw osteosynthesis. Pre-operative and post-operative lateral oblique radiographs, chosen for their ability to ensure strict identicality of projection, showed that condylar displacements commonly occurred. Anterior displacements were most commonly found, especially when screw osteosynthesis was used, and displacement with a change in axial inclination occurred in 72% of the cases. Condylar axis rotation was seen to be almost exclusively inward.

As can be inferred from the previous study, rigid fixation was used in Europe during the 1970s after first being described in the German literature by Spiessl in 1974 for use with mandibular retropositioning via the sagittal split osteotomy (135). The technique was subsequently described in English in 1976 (136) but became more widely

used after it was described in a United States' scientific journal in 1982 (137). The use of rigid fixation with vertical ramus osteotomies has been described (78) but the literature is lacking regarding its success in preventing relapse over the long-term.

In 1982, Paulus and Steinhauser (99) evaluated the long-term results (approximately two years post-surgery) of one hundred twenty one patients surgically treated for mandibular prognathism. Eighty three patients were treated with sagittal split set-backs of which forty had wire osteosynthesis and forty three had screw osteosynthesis; thirty eight patients were treated with vertical ramus osteotomies with thirteen having had wire osteosynthesis and twenty five having had screw osteosynthesis. Serial cephalographs were evaluated as well as were cast models. Sagittal relapse was defined as an incisal edge-to-edge or anterior cross-bite occlusion whereas vertical relapse was defined as an edge-to-edge or open bite occlusion of the anterior teeth; SNB and lower face height was also evaluated. Following sagittal split osteotomies, horizontal occlusal relapse was seen in 7% of the cases with bone screw fixation compared to 17.5% of those who had wire osteosynthesis; vertical occlusal relapse was seen in 5% of those with bone screw fixation compared to 15% of the wire osteosynthesis group. Post-operative changes in SNB

of greater than one degree was seen in 53% of the wire osteosynthesis group compared to 37% of the screw fixation group while a post-operative increase in anterior face height of greater than 1 mm was seen in 63% after wire osteosynthesis versus 30% after screw osteosynthesis. Horizontal relapse after vertical ramus osteotomy was similar between the two osteosynthesis groups with the wire fixation group having 15% relapse and the screw fixation group exhibiting 16% relapse. Vertical relapse after vertical ramus osteotomy was 8% in the wire osteosynthesis group and 16% in the screw fixation group; post-operative change in SNB of greater than one degree was found in 23% of the wire osteosynthesis group and in 28% of the screw osteosynthesis patients; finally, a greater than 1 mm increase in anterior face height was seen in 38% after wire and 24% of patients after screw osteosynthesis.

In 1989, Franco and his colleagues in San Antonio (48) evaluated twenty five mandibular set-back cases done via sagittal split osteotomies with three-screw rigid fixation. Fourteen were single jaw cases while eleven had concomitant maxillary surgery which was stabilized with bone plates. Cephalometric radiographs were taken pre-operatively, one to six days post-operatively and long-term, from six months to three years post-operatively. Relapse was defined as movement of pogonion over the long-term. The results

showed startlingly high amounts of relapse with the one-jaw group having been set-back an average of 4.87 mm (range of 1.0 to 8.1 mm) and relapsing an average 2.13 mm or 43.7% of the mean surgical movement. In the two-jaw cases, pogonion was set-back a mean 5.43 mm (range of 0.5 mm to 18.0 mm) and relapsed an average of 2.9 mm or 53.4% of the set-back. Regression analysis for each group showed that the only factor to significantly predict relapse in the one-jaw cases was the magnitude of the set-back whereas the only significant predictor in the two-jaw cases was proximal segment rotation. Notably, the authors pointed out that occlusal changes were not altered due to the skeletal relapse though no details were given. Two potentially significant aspects of the study should be noted; some of the T2 radiographs were taken with the splint in place which thus required manual autorotation of the mandible on the tracings and some of the cases had a concomitant genioplasty procedure. Both of these factors add potentially significant complications to the determination of movement at pogonion. Also, though the authors did find that proximal segment rotation significantly predicted the relapse in two-jaw cases (from +4.9 degrees at T2 to -3.7 degrees at T3), they failed to mention that, though not significant in this sample, there was a definite rotation of the proximal segment in the one-jaw cases as well (from

+3.9 degrees at T2 to -2.8 degrees at T3). This may help explain the etiology of the relapse for as the proximal segment "rebounded" from the surgically-induced clockwise rotation, the distal segment followed in the same counter-clockwise direction, thereby placing pogonion more forward in the anteroposterior plane. The authors noted that no flexion occurred at the osteotomy site, no doubt due to the success of the fixation method, thus maximizing the anterior movement of pogonion as the vertical dimension decreased. If the osteotomy site had been less rigid, the suprahyoid musculature may have provided the force for flexion at the surgical cut and kept the distal segment in a more postero-inferior position during healing thereby keeping pogonion back in the anteroposterior plane.

Clinically noticeable condylar changes which would effect stability over the long-term do not appear to be a problem in mandibular set-back procedures as virtually no literature exists on this topic with regard to the surgical modalities presently in use. Certainly, condylar displacement occurs in mandibular retropositioning surgery (35, 56, 62, 66, 81, 102, 117, 120, 138, 142, 154, 165) and whether or not this displacement is resolved during fixation, at fixation release or over the long-term with condylar remodelling is probably due to a myriad of factors including the presence and type of intraosseous fixation,

muscle tone and function during fixation and various functional positioning factors including the degree of occlusal intercuspation, temporomandibular joint architecture and muscular positioning "habits". The paucity of literature on this topic is quite possibly due to the tendency to consider success in terms of anteroposterior dental occlusion instead of improved vertical and horizontal skeletal relationships. When the intraoral vertical ramus osteotomy without intraosseous fixation but with prolonged (four to eight weeks) intermaxillary fixation is the chosen surgical retropositioning technique both the alveolar bone encasing the dentition and the healing osteotomy site remodel as the condyles reseat and the dentition seeks maximal intercuspation. On the other hand, with the increased use of rigid fixation techniques and shorter-term elastic intermaxillary fixation the osteotomy site is no longer as able to adaptively remodel and the dentition is required to bear the brunt of the compensations needed to reseat the condyles and the teeth to maximally intercuspate. Given that there appear to be limits on the degree to which the adult dentition can make these compensations, especially with self-placed intraoral elastics over a constrained period of time, the future may be brighter for a more in-depth study of all aspects of mandibular retropositioning surgery and its subsequent stability.

Maxillary Osteotomies

The Le Fort I downfracture is the basis for the great majority of maxillary surgery performed in the United States today. Prior to the routine use of the Le Fort I, maxillary surgery involved isolated segmental osteotomies (75), segmental ostectomies (79, 131), isolated posterior osteotomies (7, 141, 159, 160), combined anterior and posterior osteotomies (167) and the total alveolar maxillary osteotomy (29, 58). The Le Fort I osteotomy with a downfracture of the maxilla, in one piece or in two or more segments, became the standard surgical procedure in the United States for virtually all surgical maxillary movements following the publication of Bell's work in 1975 (9, 10). Documentation of the use of Le Fort I type osteotomies for the treatment of maxillary dentofacial deformities has been in the European literature since 1927 when Wassmund reported on a circular detachment of the maxilla in the manner of a Le Fort I type fracture for correction of an open bite deformity (155). Auxhausen, in 1934, was the first to anteriorly advance a post-traumatic two piece maxilla (3). Neither surgeon separated the maxilla from the pterygoid plates and they both utilized elastic traction for post-surgical repositioning. Schuchardt was the first to separate the maxilla from the

pterygoid process in 1940 via a two-stage procedure and extraoral weighted traction repositioning (131). A variety of case reports and technique articles followed, primarily dealing with post-traumatic and cleft palate maxillary repositioning. In 1969, Obwegeser published, in English, a description of various surgical treatment modalities for the retropositioned mandible (98). One of these modalities was a high Le Fort I maxillary advancement with separation from the pterygoid plates and the routine utilization of bone grafts, a technique he had been using throughout the 1960s (97). This became the standard procedure for maxillary surgery in Europe and, subsequently, in the United States.

Maxillary Advancement

In 1971, Kufner (80) reported on sixty one patients who had undergone total maxillary advancement via modified Le Fort I osteotomies from 1966 to 1971 in Prague, Czechoslovakia. A stable functional and cosmetic improvement was seen in fifty seven patients while two patients exhibited "partial relapse" and two others displayed "complete relapse". The author attributed relapse to "insufficient occlusion for stabilization" and poor incorporation of the bone grafts. A number of critical points remained unclear from the article including

the exact nature of the surgical procedures performed, i.e., the degree to which the maxilla was mobilized, the length of time between surgery and follow-up and the specific direction or amount of movement during surgery.

The first article to give descriptive statistical data on relapse of the LeFort osteotomy appeared in a 1974 supplement to the Scandinavian Journal of Plastic and Reconstructive Surgery in which Willmar (163) described the results of one hundred six LeFort I osteotomy patients, ninety two of whom were evaluated for long-term relapse at one year post-surgery and sixty five of whom were evaluated again at three years post-surgery. The patients were divided into four groups based upon clinical, etiologic and morphologic criteria including cleft lip and/or palate patients, idiopathic and post-traumatic anterior cross-bite patients, idiopathic short face patients and idiopathic long face patients. The post-operative changes in occlusion were analyzed via dental casts and the skeletal changes were analyzed by means of positional changes of metallic implants which had been placed in the maxilla as seen in standardized cephalometric radiographs. Results showed that, by and large, the dental occlusion stayed stable throughout the observation period with only the group of male idiopathic and post-traumatic anterior crossbite patients having a 0.6 mm dental relapse at the

one year follow-up. With regard to skeletal changes in the maxilla, patients in all groups except the cleft lip and/or palate group remained horizontally stable post-surgically, while vertically, patients in the idiopathic and post-traumatic anterior crossbite group showed an upward movement of the maxilla during fixation with males having a 1.8 mm superior movement in the anterior and 0.8 mm of superior movement in the posterior maxilla while the females demonstrated a 2.3 mm elevation of the anterior and a 1.1 mm elevation of the posterior maxilla. No changes were recorded in maxillary position after the fixation period. The eight female patients with idiopathic short and long faces remained skeletally stable throughout the observation period.

In 1978, Hedemark and Freihofer in Zurich (60) reported on the vertical stability of fifteen Le Fort I advancement patients analyzed via serial cephalometric radiographs to at least six months post-surgery. Of the three cases that were tilted superiorly as well as advanced, two remained quite stable while one case which was tilted upwards 1 mm during surgery continued to move further superiorly post-operatively an additional 4 mm. Of the twelve cases that were tilted inferiorly a mean 3.2 mm (range of 1.5 mm to 5.5 mm) during surgery, only one case did not relapse superiorly during the post-operative

period and this case showed a further 1 mm inferior movement to augment the 3 mm inferior surgical movement. The remaining eleven cases relapsed approximately 75% of the inferior surgical movement and all but one of these cases completed the relapse by the time of fixation removal. The amount of relapse observed in this patient sample is remarkably high but it should be pointed out that measurements were made from SN to "in the area of the upper central incisors" which begs the question as to what, exactly, was being measured: skeletal relapse, dental relapse or both. Assuming that the combined skeletal and dental relapse was what was actually measured, it would be interesting to know the proportional relapse of each component.

Also in 1978, Araujo and his colleagues at John Peter Smith Hospital (1) analyzed the results of twenty one adult patients who had undergone maxillary advancement, the actual procedures of which were not stated, ten of whom had post-tuberosity bone grafts while the remaining eleven did not. Each group was then subclassified between those with idiopathic maxillary deficiency and those with cleft lip and/or palate. Average follow-up was approximately two years in all groups with a range of six months to over four years. There was greater stability in the bone-grafted groups with horizontal relapses from 0% to 5% of the total

advancement seen while there was a 31% to 68% relapse in the groups where grafts were not utilized as measured from the maxillary incisors. There was no essential difference in relapse rates of grafted maxillas between those patients with idiopathic maxillary hypoplasia and cleft patients; on the other hand, those non-grafted patients with idiopathic maxillary hypoplasia relapsed backwards and slightly upwards while those cleft patients without bone grafts had a horizontal relapse almost 40% less than the idiopathic hypoplasia group but had three times more vertical "relapse" as measured from A point. It is important to note that those patients who did not have bone grafts were overadvanced, approximately 30%, during surgery while those who had grafts were not. It is also important to note that the comparisons between the grafted and non-grafted patients were made with the measurements taken at the maxillary incisor which often "relapsed" in the opposite direction of its skeletal base. The authors sought to justify this by pointing out that A point and ANS were unreliable due to the location of surgical cuts and subsequent remodelling at these points. Finally, the numbers of patients upon which these measurements were made were extremely small; there were seven idiopathic maxillary deficiency patients in the non-grafted group while there were only two in the bone graft group. Given

all of these caveats as to how the measurements were obtained, the validity of the measures of "skeletal relapse" given in this paper should not go unquestioned.

In 1982 Teuscher and Sailer in Zurich (143) reported on the stability of sixteen patients randomly chosen from the sixty five dentate, adult patients who had undergone maxillary anterior repositioning. Nine of these patients had five year post-treatment cephalographs available for analysis. The mean anterior relocation of the maxilla was 7.1 mm and after one year there was a loss of 0.38 mm (5%) of the anterior position. No further horizontal relapse was noted through five years post-surgery. The authors, in their attempt to avoid vertical movement during surgery, found the vertical position of the maxilla to be stable with an average 0.83 mm downward surgical relocation and a 55 degree posterior rotation of the palatal plane which "rebounded" upward 0.60 mm and anteriorly rotated 0.79 degrees during the first year post-fixation.

In 1985, Reyneke and Masureik in South Africa (115) reported on their method of treatment of maxillary deficiency and included information on nine patients, two of whom were cleft palate patients, who had been treated with a surgical anteroinferior repositioning of the maxilla. These nine patients were followed from between seven and twenty four months (average of 14.1 months) and

were found to have a mean vertical relapse of 15% and a mean horizontal relapse of 8% though there was much individual variation. The methods of follow-up and data collection were totally absent from the report.

In 1991, Proffit and his colleagues (108) evaluated the surgical and post-surgical changes seen in forty nine patients who had undergone isolated maxillary advancement comparing pre-surgical, immediately post-surgical and at least twelve month post-surgical cephalometric radiographs. Thirty one of the patients had been fixated with wire osteosynthesis and intermaxillary fixation while eighteen had been rigidly fixated with bone plates. Half of the patients had autologous or homologous bone grafts and no patient received hydroxylapatite graft material. The average advancement was 3.9 mm at A point in the wire osteosynthesis group and 4.8 mm in the rigid fixation group. In nearly 40% of the patients, the mandible rotated posteriorly more than 2 mm due to a downward surgical movement of the maxilla and in approximately 20% of the patients the maxilla moved superiorly at least 2 mm as well as forward. Both groups exhibited a mean antero-posterior relapse of just under 1 mm through the first post-operative year. B point moved forward approximately 3 mm during the same time period due to an upward movement of the maxilla which averaged 1.5 mm anteriorly and 0.5 mm posteriorly.

Horizontal stability, defined as less than two millimeters of posterior movement at A point and ANS, was seen in three fourths of the patients while vertically, the anterior maxilla moved upward greater than 2 mm in 20% of the patients. The majority of vertical relapse occurred within the first six post-operative weeks while the horizontal changes continued throughout the entire twelve months. The authors did point out that these horizontal changes in maxillary landmarks which constituted relapse may have primarily been remodelling. Mean horizontal changes in the maxilla post-surgically were nearly identical between the rigid fixation group and the wire osteosynthesis group while vertically there was a strong tendency for those patients in whom the maxilla was moved inferiorly during surgery to exhibit vertical relapse post-surgically. Although the magnitude of this upward relapse was smaller in patients with rigid fixation, the bone plates did not prevent this upward relapse. Bone grafts had no effect on stability.

Maxillary Impaction

Willmar was the first to report descriptive statistics on the relapse of the Le Fort osteotomy. Of the one hundred six patients described in this 1974 article (163), three were classified as having idiopathic long faces which

were treated with Le Fort I osteotomies and radiographically and clinically followed for one year post-surgery. Horizontal changes were insignificant over the time period evaluated and vertical changes at the anterior marker showed a superior movement of the anterior maxilla during fixation of a mean 0.83 mm; the posterior marker did not move during the fixation period. Both anterior and posterior markers showed an insignificant inferior movement of 0.17 mm during the one year follow-up period.

In 1976, Schendel and his colleagues (128) reported on the stability of twenty three patients who had undergone superior repositioning of the maxilla for the treatment of vertical maxillary excess or bimaxillary protrusion with concomitant open bite. Averaged faces were calculated pre-operatively, immediately postoperatively and according to the longest post-operative recall cephalographic radiograph for both the vertical maxillary excess group and the bimaxillary protrusion group; the "averaged faces" were then compared to evaluate skeletal and dental changes that occurred over the four to twenty nine month recall periods. The vertical maxillary excess group of eighteen patients showed minimal dental change and minimal change at ANS. Horizontal movement at A point did show a 1.2 mm posterior movement while vertical movement at A point was minimal. Evaluation of the five bimaxillary protrusion patients

showed minimal changes in the position of the maxilla over the four to twenty month follow-up period while the maxillary first molars and the incisors did move superiorly slightly more than 1 mm over the same period. While relative stability was demonstrated in this patient cohort, a number of methodologic problems were evident. The use of "averaged face" models to determine mean relapse is less precise than simply determining the relapse of each patient and then computing the mean relapse; this analysis technique also precludes gaining any information from the range of individual relapse measurements. Also, there was some confusion as to whether the average immediate post-operative face was based on the same number of patients as the average long-term follow-up face. Finally, it is questionable whether one should consider four month post-surgery cephalographs acceptable for determination of long-term stability.

In 1977, Bell and McBride (11) reported on their technique and experiences in the surgical correction of the "long face syndrome" in twenty two non-open bite patients and nineteen open bite patients with follow-up periods of two to thirty two months (mean of 13.6 months). No statistical data was presented with regard to relapse but the authors did restate the findings given in the 1976 article by Schendel, et al that "cephalometric monitoring

after surgery has revealed only a slight tendency for the maxilla to intrude and retrude during the period of intermaxillary fixation and thereafter." (128) They went on to note that the maxillary relapse was not clinically discernable over the follow-up period.

The surgical correction of open bite was the subject of evaluation by Frost and others in North Carolina and Iowa in 1980 (51) when they compared nineteen non-growing uncorrected Class I females with thirteen non-growing females with skeletal apertognathia corrected surgically with various procedures but all having had a posterior maxillary impaction. Pre-operative, immediate post-operative and long-term cephalographs were compared for each open bite patient with the long-term follow-up averaging nineteen months, the range being seven to thirty months. No patient showed relapse to an open bite over the long-term and there was no statistically significant difference between any immediate post-operative measurement and its comparable long-term measurement.

In a 1981 report on the long-term results of superior surgical repositioning of the maxilla, Epker (40) gave his clinical impression that it was "...an extremely stable operation with a slight relapse tendency such that the maxilla tends to settle superiorly." No actual data was presented.

In 1986, Bundgaard and her colleagues in Aarhus (22) reported on the results a cephalometric evaluation of changes during and following Le Fort I osteotomies on sixteen patients with some degree of maxillary vertical hyperplasia. Comparisons of cephalometric radiographs taken prior to surgery, post-operatively and after a minimum of six months post-surgery (mean of twelve months and range of six to twenty four months) were made and analyzed with regard to relapse tendencies. The authors found that the mean stability of the hard tissue changes was high in the horizontal plane and the vertical plane posteriorly but that impaction continued at A point after the operation though there was marked individual variation. The authors did find patterns between operative and postoperative changes: in those cases where the maxilla was moved backward or forward without any rotation, hard tissue stability was nearly complete; in cases where the anterior maxilla was displaced up and back with a counterclockwise rotation to the occlusal plane, the post-operative changes were in the same direction as the surgical movements; conversely, if the maxilla was displaced up and forward, there was a tendency to relapse toward the original morphology.

In 1987, Proffit and his colleagues in North Carolina (110) cephalometrically analyzed sixty one patients who had

undergone superior maxillary repositioning via a Le Fort I osteotomy. None of the patients had concurrent mandibular surgery, except genioplasties and rigid fixation was not used on any of the patients. The average superior movement at A point during surgery was 3.82 mm with an additional superior movement of 1.04 mm during fixation and a 0.72 inferior movement post-fixation. The posterior maxilla was moved superiorly during surgery an average of 2.08 mm with and additional 0.29 mm movement upward during fixation and a 0.21 mm movement downward in the post-fixation period. Horizontal movement at A point averaged 0.94 mm of anterior movement during surgery with a subsequent posterior relapse of 0.24 mm during fixation and an additional 0.69 mm posterior movement post-fixation. The posterior maxilla moved an average of 1.35 mm forward during surgery and relapsed 0.22 mm during fixation and an additional 0.17 mm post-fixation. The authors considered a 2 mm post-surgical movement in either a vertical or horizontal direction as indicative of instability and they found that, during the first six weeks post-operatively, the posterior maxilla remained stable in 90% of the patients and the anterior maxilla was stable in 80% of the patients, however in those patients that did show instability, there was a strong tendency for the maxilla to continue moving superiorly. Horizontally, skeletal landmarks were stable in 80% of the

patients but when changes occurred, there was a tendency for the anterior maxilla to relapse backward when it had been advanced. After the fixation period, the posterior maxilla was vertically stable in all patients but 20% of the patients had downward movement in the anterior maxilla, opposite the direction of movement that occurred during fixation. In all, four patients (6.5%) had 2 mm or greater net vertical change after one year post-surgery. There was no correlation between instability and pre-surgical orthodontics, multiple segmentation during surgery, the age of the patient, the use of suspension wires or the identity of the surgeon.

In 1988, Bishara and his colleagues in Iowa (16) cephalometrically evaluated the stability of thirty one patients who had been previously treated for vertical maxillary excess with a Le Fort I impaction. Radiographs taken prior to surgery, immediately after surgery, during fixation (mean of thirty seven days post-surgery with a range of twenty one to forty eight days) and post-fixation (mean of nineteen weeks post-surgery with a range of nine to twenty seven weeks) were compared for skeletal changes. The authors found that, in the vertical plane, the anterior maxilla was moved superiorly an average of 3.0 mm during surgery and moved 0.87 mm further superiorly during fixation with no subsequent movement post-fixation while

the posterior maxilla moved superiorly 3.5 mm during surgery, moved an additional 0.69 mm during fixation and moved inferiorly 0.26 mm postfixation. This amounted to a 33% increased superior movement of the anterior maxilla post-surgery and a 12.3% increased superior movement post-surgery of the posterior maxilla. Horizontally, the anterior maxilla was moved anteriorly during surgery an average of 2.54 mm, it moved posteriorly 0.52 mm during fixation and an additional 0.50 mm post-fixation; the posterior maxilla was moved an average of 2.59 mm anteriorly at surgery and it relapsed 0.53 mm during fixation with an additional posterior movement of 0.30 mm post-fixation. Overall, the anterior maxilla relapsed posteriorly an average of 39.8% and the posterior maxilla relapsed an average of 32.0% over the time period evaluated. Dentally, the vertical post-surgical movement at the maxillary incisors was a 47.3% increase in superior positioning with an 8.6% increased superior movement at the molars. Horizontally, there was a 26.8% posterior relapse at the incisors and a 23.7% relapse at the upper molars. Finally, of the thirty one cases presented, twelve had open bites however the presence of a pre-surgical open bite did not significantly alter the magnitude of post-surgical change and there was no clinically observable change in the overbite relationship of any patient in the post-surgical

period evaluated.

In 1989, Denison and his colleagues in Seattle (32) radiographically evaluated the long-term stability of maxillary impaction of sixty six Le Fort I osteotomy patients who were divided into three groups based on their degree of pretreatment overbite: a pre-treatment open bite subsample, an overlap subsample which did exhibit incisal overlap but without incisal contact and a contact subsample which exhibited both incisal overlap and contact. Pre-treatment, post-treatment and at least one year post-treatment radiographs were superimposed and compared. The authors found that approximately 43% of the open bite subsample showed long-term relapse of a clinically and statistically significant increase in facial height, eruption of the maxillary molars and decrease in overbite. Another 29% of the open bite subsample plus 17% of the overlap subsample showed a clinically and statistically significant long-term increase in facial height and maxillary incisor eruption but without a change in overbite. The contact subsample and 83% of the overlap subsample exhibited no clinically significant long-term changes while six patients (21%) in the open bite subsample had their open bite reopen beyond incisal overlap over the long-term. Interestingly, no correlations were found between treatment changes and long-term relapse in any of

the three groups. The authors felt that, though there was rather substantial relapse in the open bite subgroup after Le Fort I surgery, the data indicated that the instability was due to dentoalveolar changes post-treatment and not to skeletal relapse and that perhaps aberrant orofacial musculature, i.e. tongue posture and hypotonic buccal musculature, may be a significant contributor to post-treatment open bite relapse.

Three years later Bishara and Chu (15) cephalometrically evaluated twenty three one piece maxillary impaction patients and eight one piece maxillary advancement patients, neither group having been stabilized rigidly, and compared stability parameters between the two groups. Interestingly, the skeletal vertical change during the fixation period was greater in the advancement group with an additional 1.87 mm of superior movement during fixation after the initial 0.51 mm average superior movement during surgery. In contrast, the maxillary impaction group was moved superiorly 3.86 mm during surgery and had an average 0.52 mm continued superior movement during fixation.

Maxillary Inferior Repositioning

One of the first refereed articles to discuss stability of surgical maxillary inferior repositioning in

non-cleft patients was a 1974 article by Willmar (163) in which five patients with "idiopathic short face syndrome" who had undergone Le Fort I osteotomies were evaluated cephalometrically with the aid of maxillary implants. No significant mean changes were found in the vertical or horizontal position of the anterior and posterior maxilla during fixation or at the one and three year post-operative evaluations.

In 1977 Bell (8) described the diagnosis and treatment of patients with "short face syndrome". He reported on two cases who had been surgically treated and who had an average inferior repositioning of approximately 6 mm. One case exhibited "significant" skeletal relapse of approximately one third of the surgical movement occurring within ten months of the surgery while the second case exhibited a 29% relapse during intermaxillary fixation.

In 1981 Freihofer (49) reported on the surgical modalities utilized in the treatment of short-faced patients, including Le Fort I advancement and inferior positioning. Though no statistical data was presented, the author did state that vertical lengthening of the maxilla was subject to high relapse potential, that a fifty percent overcorrection should be included in the surgical movements and that rigid stabilization should be utilized.

That same year, Wolford and Hilliard (168) discussed

the surgical correction of vertical maxillary deficiency in an article which emphasized diagnosis. They did, however report that relapse after surgical inferior repositioning, via a presumed Le Fort I osteotomy and bone grafts, was a significant problem with 20% to 70% vertical relapse seen in their patient population, though the exact number of patients was unreported. They recommended the use of pre-surgical occlusal splints and Steinman pin stabilization post-surgery in order to attempt to minimize relapse.

Again that same year, Bell and Scheideman (12) followed up on Bell's 1977 (8) article and reported on the long-term results of eleven patients with vertical maxillary deficiency who were treated by Le Fort I osteotomy and autogenous interpositional bone grafts. The patients were fixated with interosseous wires and, in six cases, with suspension wires as well. Intermaxillary fixation ranged from two days to seven weeks with a mean of approximately 4.5 weeks and follow-up ranged from six to thirty five months post-surgery with a mean of twelve months. Mean relapse was 31.4% or 1.9 mm of a mean 6.8 mm surgical inferior movement, though three patients had no relapse and one patient had 100% relapse. There was no significant correlation between the amount of surgical movement and either the magnitude of relapse or the percent of relapse. All relapse occurred during the first two to

three months post-surgery with minimal movement thereafter.

The last, and probably least of the 1981 articles on the surgical treatment of vertical maxillary deficiency, was by Wessberg and Epker (157) who reported on the surgical management of patients needing maxillary inferior repositioning in order to "ensure predictable and stable results." Photographs of two patients who had successfully undergone the procedure were included though no descriptive statistical data was given nor was a follow-up status reported.

In 1990, Rosen (119) reported on the long-term stability of nine patients who were treated with inferior maxillary repositioning via Le Fort I osteotomy, porous block hydroxyapatite grafts and rigid fixation without any intermaxillary fixation. Concomitant surgeries included four mandibular advancements and four vertical augmentation genioplasties. Evaluation was via serial cephalometric comparison and follow-up ranged from eleven to twenty eight months. Long-term relapse was found to be 4.3% with no patient exhibiting a difference in vertical measurements between the immediate post-operative cephalograph and the long-term cephalograph of more than 0.5 mm, a truly remarkable finding considering that hard tissue measurements were taken at nasion, ANS and menton with ANS being surgically altered in all nine cases and menton being

surgically altered in four cases and subject to post-surgical "settling" in the four mandibular advancement cases.

Fixation of Maxillary Osteotomies

In an effort to maximize long-term stability, a number of different measures have been suggested to augment intraosseous and suspension wires. Interpositional bone grafts with a variety of materials (1, 12, 23, 41, 42, 70, 153, 168), surgical modifications (68) and a variety of fixation techniques including Steinman pins (14, 168), rigid adjustable pins (5, 6), intraoral skeletal fixation appliances (157) and bone plates (34, 63, 89, 140, 101, 149, 153) have been utilized. The great majority of articles addressing this subject are technique and clinical impression articles. Very few case series have a large number of patients, long-term follow-up or rudimentary descriptive statistics. The exceptions to this generalization are as follows.

In 1985, Luyk and Ward-Booth (89) reported on the stability of maxillary advancements in eleven patients, three of whom were cleft lip and/or palate patients and seven of whom had concomitant mandibular surgery, utilizing four Champy mini-plates and no bone grafts. Serial cephalometric radiographs through six months post-surgery

were evaluated for skeletal changes and no significant relapse was found. The authors did note, however, that there were individual differences and some of the cleft patients had large amounts of post-surgical skeletal change.

In 1988, Rondahl and his colleagues in Stockholm (118) cephalometrically compared ten patients who had received intraosseous fixation during Le Fort I maxillary advancement surgery with fourteen patients who had received intraosseous fixation with suspension wires and/or bone plates following the same type of surgery. Both groups had bone grafts placed and were placed into intermaxillary fixation for five to six weeks. The surgical movements were quite similar between the two groups with the maxilla of the intraosseous fixation group having been moved anteriorly 5.6 mm, inferiorly 2.0 mm and rotated 3.2 degrees downward and backward. The enhanced fixation group had mean maxillary movements at surgery of 5.9 mm anteriorly, 1.2 mm inferiorly and were rotated 2.9 degrees in a downward and backward direction. During the immediate post-operative period to fixation release, the intraosseous fixation group relapsed a mean 1.1 mm vertically (55% of the original movement) while the enhanced fixation group relapsed 0.2 mm vertically (15% of the original movement); the horizontal dimension remained stable in both groups

during this time period. From fixation release to follow-up twelve to twenty four months later, vertical and rotational stability was seen in both groups while, in a horizontal dimension there was a mean 1.0 mm posterior relapse in the intraosseous fixation group and a mean 0.6 mm posterior relapse in the enhanced fixation group. The authors concluded that rigid vertical fixation was important for skeletal stability of maxillary advancements.

In 1989, Wardrop and Wolford (153) reported on a series of twenty four patients, eleven maxillary inferior repositionings, fourteen maxillary advancements and three modified Le Fort III advancements, who had undergone at least five millimeters of maxillary inferior or anterior surgical movement and were fixated with porous block hydroxyapatite grafts, rigid stabilization and up to two days of intermaxillary fixation. Each patient had a minimum of sixteen months follow-up. Vertical stability was measured for the downgraft patients while horizontal stability was measured for the remaining patients. Results showed that all patients had 1 mm or less relapse over the long-term. The average anterior surgical movement in the inferior repositioning patients was 5.4 mm with a mean 0.5 mm vertical relapse; posteriorly the average movement was 3.8 mm with a mean 0.4 mm vertical relapse. The maxillary advancement patients had an average anterior surgical

movement of 6.1 mm with a mean horizontal relapse of 0.4 mm while posteriorly there was a mean surgical movement of 6.6 mm with a relapse of 0.2 mm on average. The Le Fort III patients had a mean advancement at the anterior maxilla of 4.8 mm with an average horizontal relapse of 0.3 mm. The authors did present three cases, not included in the series, in which relapse did occur to a greater degree and they attributed the relapse to migration of the bone plates through very thin maxillary bone in all three cases.

Also in 1989, Larson and her colleagues in San Antonio (84) compared the serial cephalograms of seventeen Le Fort I patients who had intraosseous fixation plus six weeks of intermaxillary fixation to thirteen patients who had been fixated with bone plates and two days of intermaxillary fixation through at least one year post-surgery. No trauma or craniofacial anomaly patients were included in the sample. The results showed no significant difference between the two groups during the first six weeks, nor during the first six months post-surgery. Over the longer term however, the rigid fixation group was shown to be more verticallly stable during the six month to one year time period as well as during the overall time period of immediate post-surgery to one year post-surgery. The overall vertical movement in the non-rigid fixation group averaged 1.7 mm while the rigid group averaged 0.9 mm.

Interestingly, in the horizontal plane, the rigid fixation group averaged 2.0 mm relapse while the non-rigid fixation group averaged only 1.2 mm. Due to the discrepancy in stability findings between the vertical and horizontal planes, further discussion was probably warranted as to why the authors felt that overall stability was greater in the rigid fixation group.

Bimaxillary Procedures

In 1980, Brammer and his colleagues in Dallas (20) cephalometrically evaluated twelve female patients between the ages of eleven and twenty nine (mean of twenty years) who had undergone a Le Fort I impaction and advancement along with bilateral sagittal split osteotomies with or without genioplasty in order to treat vertical maxillary excess, mandibular deficiency and, in six cases, anterior open bite. Adjunctive treatment to the primary surgical procedure was individualized for each of the eleven patients with eight of the patients having been treated orthodontically, two patients had segmentalized maxillary osteotomies, four patients had concomitant genioplasty, nine patients had suprahyoid myotomies, seven patients wore cervical collars post-operatively and five patients had interocclusal splints during intermaxillary fixation. Follow-up ranged from 4.5 to 20.5 months with a mean of

eight months. In the horizontal plane, A point was moved a mean 3.3 mm anteriorly during surgery and relapsed a mean of 1.0 mm (30% relapse); PNS was moved 3.0 mm during surgery and relapsed a mean 0.6 mm (20%); B point was surgically repositioned a mean 12.8 mm forward and relapsed 1.8 mm (14%); pogonion was moved a mean 16.1 mm surgically and relapsed a mean 2.7 mm (17%). In the vertical plane, A point was repositioned a mean 3.1 mm superiorly during surgery and relapsed 0.4 mm (13%); PNS was surgically placed 2.3 mm superiorly and relapsed 0.1 mm (4%); B point was raised 2.1 mm during surgery and continued to move superiorly 0.7 mm post-surgery and pogonion moved 1.6 mm inferiorly during surgery and moved superiorly 1.9 mm during follow-up (119%). Considering mean angular changes post-surgery, SNA increased 2.5 degrees during surgery and relapsed one degree (40%), SNB increased 6.7 degrees and relapsed 1.2 degrees (18%) and MPA decreased 8.4 degrees but relapsed 3.3 degrees (39%). The authors discussed a number of correlations that were found in this study including, the greater the anterior movement of the mandible at surgery, the greater the relapse; superior repositioning of the posterior maxilla was strongly correlated with decreased mandibular relapse; greater maxillary intrusion was associated with decreased posterior movement of the maxilla during follow-up; and posterior

maxillary relapse was closely related to the magnitude of the mandibular advancement. The authors concluded that there was good stability following bimaxillary surgery and that the mandibular stability was a function of both the magnitude of advancement and the degree of maxillary impaction.

In 1982, LaBanc with a colleague in Texas and Turvey in North Carolina (82) reported on a retrospective cephalometric study of one hundred consecutive patients who had undergone bimaxillary osteotomies for a number of dentofacial deformities. Their sample included fifty six Class II skeletal deformities, forty four of whom also had vertical maxillary excess, twenty six Class III skeletal deformities, ten facial asymmetries, five Class I deformities and three miscellaneous problems. The surgical interventions included ninety seven Le Fort I osteotomies, three Le Fort III osteotomies, eighty two sagittal split osteotomies and eighteen other ramus osteotomies. No statistical data on relapse was presented in this article but the authors did discuss apparent post-surgical sequelae which led, in some cases, to short or longer-term relapse including, a short-term postero-inferior relapse of the entire maxillomandibular complex secondary to inadequate posterior maxillary "bony interfaces" which the authors felt could be prevented with the use of skeletal fixation,

short-term relapse secondary to inadequate condylar seating intra-operatively and a delayed Class II, open-bite relapse secondary to "condylar resorption or negative remodeling" seen six to twenty four months post-surgery.

Stability of bimaxillary procedures fixated with intraosseous wires, skeletal fixation and intermaxillary fixation was reported by Turvey and his colleagues in Chapel Hill in 1988 (147). Fifty three patients who had undergone simultaneous maxillary impaction and bilateral sagittal split osteotomy advancement were evaluated clinically and cephalometrically at least one year after their surgery. The net effects of post-surgical movement from immediately after surgery to the longest follow-up (mean of 2.4 years) were negligible in the vertical plane and, in the horizontal plane, a mean posterior relapse at pogonion of approximately 20%. Clinically, satisfactory or better results were seen in 79% of the patients at their longest follow-up evaluation. The presence of a pre-surgical open bite was the only significant variable associated with clinical outcome as a pre-surgical open bite was present in ten of the eleven patients who had a poor clinical result. The authors did not feel that these results indicated that bimaxillary surgery is generally unsuccessful for open bite closure however, since 59% of the cohort had an anterior open bite with high mandibular

plane angles (mean of 43 degrees) pre-surgically. Interestingly, there was no statistically significant relationship between cephalometric stability and clinical outcome in this cohort.

Stability of bimaxillary procedures fixated rigidly was reported on by Hennes and his colleagues in 1988 (61). Twenty-four Class II, non-growing patients were serially cephalometrically evaluated with the longest post-operative follow-up averaging 9.1 months. During surgery the maxilla was downfractured in either one or two pieces and fixated with four or five Champy mini-plates; the mandible underwent bilateral sagittal split osteotomies fixated with three screws per side, the first ones on each side being lagged while the remaining two were threaded bicortically in an effort to avoid proximal segment torque; elastic intermaxillary fixation was utilized for an average of two days. Cephalometric analysis showed that during surgery, a mean 2.0 mm of maxillary forward positioning occurred with an anterior superior movement of 4.3 mm and a posterior superior movement of 3.5 mm occurred. In the mandible, the distal segment moved 10.3 mm forward and rotated counterclockwise as seen by a 2.2 mm superior placement of pogonion; the proximal segment rotated forward but vertically remained unchanged. Posterior face height was unchanged while anterior face height decreased 1.9 mm

and the mandibular plane angle decreased 4.8 degrees during surgery. Significant post-operative movement occurred in only four parameters including horizontal movement at A point of 0.7 mm backwards, the mandibular distal segment continued autorotation with a 0.9 mm superior placement of pogonion, the posterior face height decreased 0.6 mm and gonial arc radius decreased 0.4 mm. No correlations were found between any surgical movements and subsequent post-operative changes, no correlations were found relating post-operative changes between the maxilla and the mandible, the pre-operative mandibular plane angle did not correlate to any post-operative movements and the inclusion of an advancement genioplasty in the surgical treatment showed no statistical differences with post-surgical movements of patients who did not undergo genioplasty. The authors then compared their findings to a group of patients who had undergone isolated mandibular advancements of the same magnitude, that were rigidly fixated and were operated on by the same surgical team. No statistical difference in relapse between the groups was found. The authors concluded that, when rigidly fixated, mandibular stability was not related to concurrent maxillary impaction.

That same year Skoczylas and his colleagues in Michigan (134) compared fifteen patients who had undergone rigidly fixated bimaxillary surgery to fifteen patients who

had undergone the same surgical procedures but were fixated with intraosseous wires augmented with skeletal fixation. Rigid fixation involved the placement of four bone plates in the maxilla, six bone screws in the mandible and no intermaxillary fixation. Both groups evaluated from serial cephalographs through splint removal/fixation release at eight weeks in the non-rigid fixation group and at four weeks post-fixation in the rigid fixation group. There was no statistically significant difference in post-surgical movement between the groups in any parameter measured except for a continued intrusion of the maxillary first molar an average of 1.0 mm in the non-rigid fixation group. Though not statistically significant, B point relapse was only 5% in the rigid fixation group compared to 18% in the non-rigid fixation group eventhough the rigid fixation group was advanced significantly further than the non-rigid fixation group (5.36 mm vs. 3.45 mm of advancement). It was also pointed out that, despite the lack of significance of post-operative movement between the two groups, there was more variability in the post-operative movement in the non-rigid group with twenty "unfavorable" post-operative changes versus eight "unfavorable" changes in the rigid fixation group.

The following year, Law and his colleagues (85) reported the results from cephalometric evaluation of

sixteen patients simultaneously treated with a Le Fort I and sagittal split set-back or advancement plus rigid fixation (Steinman pins and bone plates in the maxilla and three bone screws per side in the mandible). Follow-up averaged nine months with a range of six to sixteen months. Post-operative movements were generally less than 1 mm for linear measurements and less than two degrees for angular measurements. Those procedures that historically have shown the most relapse did have slightly more relapse propensity than the rest of the sample. Two patients underwent maxillary inferior repositioning an average of 6.6 mm and showed a mean relapse of 0.9 mm (14%). Four patients who underwent the largest mandibular advancements (range of 8.4 to 10.4 mm) exhibited a mean relapse of 1 mm compared to the remaining nine mandibular advancement patients with advancements in the range of 3.6 mm to 6.1 mm who had a mean post-surgical increase at B point of 0.8 mm.

In 1991, Satrom (125) published the results of a study of thirty five patients who had undergone simultaneous maxillary impaction and mandibular advancement, twenty six with rigid fixation and nine with wire and skeletal fixation. Cephalometric follow-up averaged fifteen months with a range of eight to twenty four months. Horizontally, there was no statistical difference in maxillary relapse whereas in the vertical plane, the rigid fixation group

exhibited greater stability though it was not statistically significant. In the mandible, there was a greater change in SNB in the wire fixation group which was statistically significant. Approximately the same percentage of patients in each group relapsed greater than one millimeter, although the wire fixation group tended to relapse posteriorly while the rigid fixation group showed both anterior and posterior post-operative changes. Fifteen percent of the rigid fixation group exhibited mandibular horizontal relapse of greater than 2 mm while thirty three percent of the wire fixation group showed this degree of relapse. There was no correlation between the amount of surgical movement and the amount of relapse in the rigid fixation group while in the wire fixation group, B point relapse was correlated to the amount of surgical advancement, relapse of total mandibular length and relapse in SNB. The authors concluded that rigid fixation provided superior stability overall, especially in the mandible.

In contrast to the previous studies that dealt primarily with bimaxillary surgical correction of skeletal Class II dentofacial deformities, in 1980 Moser and Freihofer from Zurich reported (96) on twenty five extreme skeletal Class III patients who had undergone maxillary advancement and mandibular sagittal split set-back procedures simultaneously. The patient cohort included

seven cleft lip and/or palate patients but did not include patients with pre-operative open bites. The mean follow-up was four years with a range of one to nine years. Occlusally, over the long-term, seventeen patients remained absolutely stable, four showed a slight change in occlusion, four relapsed to an edge to edge incisor relationship and no patient regained anterior cross-bite. Cephalometrically, twenty one patients were evaluated and it was found that eight patients remained totally stable in both jaws, eight patients remained stable in the maxilla and in eight of the nine remaining patients, the maxilla moved in an anterosuperior direction while one patient showed a small backward movement of the maxilla. In the mandible, five patients exhibited partial relapse of the mandibular set-back with four of these patients had a clinical edge to edge anterior occlusion.

In 1991, Proffit and his colleagues in North Carolina (109) also reported on the stability of bimaxillary surgical procedures used to treat skeletal Class III deformities. Fifty-one patients, none of whom had a cleft lip and/or palate, were included in the serial cephalometric study. Each patient had undergone bimaxillary surgery consisting of a Le Fort I osteotomy with either superior repositioning or with an advancement of at least two millimeters plus bilateral sagittal split

set-backs of at least two millimeters. Conventional wire fixation with intermaxillary fixation was utilized in the majority of cases while rigid fixation was used when the maxilla was moved inferiorly. A post-operative movement of two millimeters or more through one year was considered to be outside of random error and therefore was used as the criteria upon which to judge significant post-surgical movement. Results were sub-divided into three groups based upon the type of surgical movements that occurred. In the group of patients in which the maxilla was moved superiorly, A point remained vertically stable after surgery and averaged only 0.5 mm of posterior relapse through one year. B point moved forward 1.3 mm during fixation and then rotated up and forward at fixation release. None of these fourteen patients had A point move more than 2 mm back or down, though 30% had their maxillary incisors move forward 2 to 4 mm. In approximately 15% of the group, B point moved forward 4 mm or more and an additional 45% of the patients had B point movement of 2 to 4 mm.

In the minimal vertical change group of twenty one patients, A point remained stable horizontally but did move superiorly, with a mean superior relapse of 2.7 mm eventhough the mean inferior movement of the anterior maxilla at surgery was only 2.0 mm. The mandible came

forward an average of 3.0 mm at B point, the majority of the movement occurring post-fixation. Within this sub-group, 20% had maxillary posterior relapse of greater than 2 mm, 50% had anterior maxillary superior movement of more than 2 mm with 25% showing posterior maxillary intrusion as well.

Within the sub-group in which the posterior maxilla was inferiorly positioned, there was good horizontal stability at A point but vertically showed a 39% relapse in the posterior maxilla with a 74% relapse in the anterior. B point moved anteriorly more than 5 mm, reflecting the autorotation produced secondary to the maxillary relapse. Within this sub-group 25% of the patients had their maxilla move posteriorly more than 2 mm and in 12% of the patients the maxilla moved more than 2 mm anteriorly. Greater than 2 mm of posterior maxillary superior movement was seen in 25% of the patients and 62% had this degree of superior movement in the anterior maxilla. Two thirds of the patients exhibited a forward movement at B point of more than 4 mm. Among all of the patients, there was no statistical difference in post-surgical movement between the rigid and non-rigid fixation groups though the surgical movements were much larger in the rigid fixation group.

Comparing this patient cohort with cohorts of single jaw surgery from the same institution, the authors felt

that, within the long-face Class III patient group, stability was excellent and better than that seen in mandibular set-back alone. In the patient group where little vertical change occurred during surgery, the authors concluded that stability was reasonably good but equivocated when comparing the outcome of two-jaw surgery to either maxillary advancement alone or mandibular set-back alone. Finally, within the short-face Class III group, the authors felt that vertical stability was greater following two-jaw surgery than following maxillary inferior positioning alone though the comparison was difficult due to the small number of maxillary inferior positioning patients to which they could compare.

Most reports on stability of bimaxillary surgery are short to medium term studies. This is probably understandable given the general findings from most of these studies showing the majority of vertical relapse occurring during fixation or within the first six to eight weeks after surgery while the great majority of horizontal relapse occurs within one year of surgery. Nonetheless, as was seen from the longer-term reports of mandibular advancements, condylar changes can have a detrimental effect on stability and the potential of similar changes occurring following bimaxillary procedures certainly exist.

In 1985, Sesenna and Raffaini (132) reported on the

case of a thirty three year old woman with a diagnosis of Class II open bite with only first and second molar occlusion who had undergone a Le Fort I maxillary impaction, 5 mm anteriorly and 3 mm posteriorly, and a sagittal split advancement with counterclockwise rotation. Rigid mandibular fixation was said to have been utilized by the authors though reproductions of the radiographs indicated that intraosseous wires were used in the maxilla and mandible along with perizygomatic suspension wires; intermaxillary fixation was left in place for eight weeks. The clinical exam with radiographs at fixation release and at the one year follow-up did not reveal any skeletal or occlusal relapse. At twenty months post-surgery, however, a 1.5 mm anterior open bite was seen at exam and was reported to have been present for three months. The patient's dental practitioner had attempted to treat it with posterior occlusal reduction. It was stated that a lateral cephalometric radiograph showed "extensive bilateral condylar resorption" and, by three years post-surgery, significant diminution of both condyles was clearly seen on a panoramic radiograph. The patient subsequently underwent an anterior mandibular subapical osteotomy and genioplasty and appeared stable after one year.

Kerstens and his colleagues in Amsterdam (71) reported

in 1990 on the results of a retrospective cephalometric study of two hundred six patients who had undergone orthognathic surgical treatment by one of two surgeons at the same institution. A Le Fort I osteotomy was utilized for maxillary procedures, sagittal split osteotomies were utilized for mandibular advancements and intraoral vertical ramus osteotomies were the surgical procedure used to treat mandibular prognathism. No intraosseous wiring was used with the vertical ramus osteotomies though wire osteosynthesis was always used with the other two procedures; all patients had skeletal and intermaxillary fixation. Each patient underwent radiographic surveys consisting of cephalograms, transcranial radiographs and panoramic radiographs at the pre-operative, immediately post-operative and at least one year post-operative examinations. Tracings were made of the radiographs if "evidence of osteoarthritic changes of the condyle" were visualized at the longest post-operative survey. The authors found radiographic evidence of pathologic condylar changes in twelve of the patients with nine patients exhibiting unilateral condylar bone loss and three patients demonstrating bilateral atrophy. All twelve patients had a pre-operative diagnosis of high-angle mandibular retrognathia and eleven had undergone bimaxillary surgery. Three of the patients had demonstrated evidence of earlier

condylar change in their pre-operative radiographs and the authors stated that in 87% of these patients the condyle was more posteriorly located than in the earlier radiographs. The authors also stated that the greatest amount of bone loss was located in the anterior of the condyles. Explanation of a number of critical procedural points were not in evidence. For instance, no mention was made of occlusal changes in the condylar atrophy patients nor was skeletal relapse evaluated; no discussion was given to the methods of evaluating the radiographs nor to any measures that may have been taken to ensure the reliability of the serial tracings.

More recently, De Clercq and his colleagues in Brugge (31) reported in 1994 on the results of a retrospective cephalometric study of twenty nine high angle mandibular deficiency patients, twenty three of whom had a concomitant open bite, who had been treated with bimaxillary osteotomies at the same institution over a three year period. Maxillary surgery consisted of a Le Fort I procedure and bilateral sagittal split osteotomies were used to advance the mandible. Pressure was utilized to seat the proximal segment completely as it was "pushed strongly in a posterior direction with a gauze packer ...fitted on the upper side of the vertical osteotomy line of the proximal segment." Monocortical plates were then

placed and only light elastic intermaxillary fixation for two weeks was utilized. Cephalograms taken within forty eight hours after surgery were compared to a minimum of two year follow-up cephalograms for data collection. Articulare to "the nearest edge of the miniplate" was used to measure mandibular shortening which was precise to one half of a millimeter. Any decrease in this measurement was considered "condylar resorption." Fourteen patients exhibited no "condylar resorption", six patients exhibited less than 2 mm of "resorption" and nine subjects had more than 2 mm of mandibular shortening. The authors considered a decrease from articulare to the miniplate of greater than 2 mm to be evidence of de facto condylar resorption as this was more than six percent of total ramus length, the point at which they accepted that loss of ramus length exceeded condylar remodelling. All nine patients with greater than 2 mm of loss of ramus length were female between the ages of sixteen and thirty one years; there was no correlation between magnitude of mandibular advancement and "resorption" nor was pre-operative temporomandibular joint symptomatology a predisposing factor. Unfortunately, important methodologic problems exist in this study which belie the significance of the findings. Nonetheless, the findings of these preliminary studies certainly indicate that further research on the prevalence of long-term condylar change is in order.

STATEMENT OF THESIS

The primary purpose of this investigation is to estimate the prevalence of moderate to severe occlusal change following combined orthodontic and orthognathic surgical treatment performed at least six years previously.

METHODS AND MATERIALS

Study Design

This is a descriptive, cross-sectional study which estimates the prevalence of moderate to severe occlusal change following combined orthodontic and orthognathic surgical treatment of patients treated during the decade of the 1980s by two oral and maxillofacial surgery practices in northeast Ohio.

Study Sample

Those subjects eligible for inclusion in this study were all patients treated with a combination of orthodontics and orthognathic surgery from two oral and maxillofacial surgical practices in the northeast Ohio area whose surgery was completed between January 1, 1980 and December 31, 1989. The surgical procedures considered for inclusion in this study were all mandibular, maxillary and bimaxillary orthognathic procedures, except for genioplasties not done concurrent with other orthognathic procedures. Those patients not included in the study were those with a known or presumed craniomandibular disorder,

including cleft lip and/or palate, patients who did not have bilateral molar occlusion and natural maxillary and mandibular incisors, patients who had not reached their eighteenth birthday by January 1, 1995, patients who had undergone surgery prior to the age of fourteen years and zero months, prisoners or persons not mentally able to read and comply with the directions needed for inclusion in the study.

From a comprehensive list of all orthognathic surgery patients meeting the inclusion criteria of this study, 294 patients were randomly chosen to be contacted for inclusion in the study. One hundred forty six persons agreed to participate in the study and were sent the materials to be completed for assessment of significant occlusal change. One hundred thirty two persons returned those materials by February 1, 1996 which thus constituted the study sample for this investigation.

Data Collection

Pilot Study

In order to determine whether or not a self-administered wax bite registration and overjet marking system sent through the federal mail was both durable and accurate enough to be utilized for the prevalence

investigation, a pilot study was designed to evaluate the accuracy and durability of three different wax bite materials and one overjet registration method. This pilot study was completed in its entirety prior to any data collection in the prevalence investigation.

Four people, none of whom had any special expertise in the dental field, were mailed three different wax bite registration materials: wax #1 being a 1/2 inch thick, horseshoe of pink wax manufactured by Modern Materials, wax #2 being a 9 mm thick, notched, trapezoid of pink wax manufactured by Allesee Orthodontic Appliances, Inc. and wax #3 being a 5 mm thick, horseshoe of Aluwax manufactured by Aluwax Dental Products Company. Each person was also mailed three overjet registration sticks, a small pencil with which to mark the sticks, written directions as to how to complete the bite and overjet registrations, an informed consent form, three orthodontic retainer cases in which to place the completed wax bites and three pre-addressed, stamped, padded mailers in which to return the completed materials. Each person followed the written instructions and registered their bite on each of the wax forms as well as their overjet on the overjet registration sticks. They then returned them via the federal postal service. This entire process was repeated two additional times for a total of nine bite registrations, three of each sample, and

nine overjet registrations per person.

The principal investigator made the following measurements or evaluations from each returned wax sample:

- the presence of any anterior open bite,
- any posterior open bite from canine to second molar,
- anterior crossbite,
- unilateral or bilateral posterior crossbite,
- maxillary intercanine distance measured from cusp tip to cusp tip,
- maxillary intermolar distance measured from the mesiobuccal cusp tips of the maxillary first molars,
- maxillary intermolar distance measured from the central fossae of the maxillary first molars,
- maxillary intermolar distance measured from the mesiolingual cusp tips of the maxillary first molars,
- mandibular intermolar distance measured from the mesiobuccal cusp tips of the mandibular first molars and
- mandibular intermolar distance measured from the central fossae of the mandibular first molars.

Evaluations were described dichotomously while measurements were taken on a Helios gauge and made to the nearest tenth of a millimeter. The measurements were then averaged and this mean measurement was compared to the comparable measurement taken from mounted, die-stone models which the

principal investigator had previously made and had verified by direct measurement on each test subject. Measurement error was determined for each type of wax by making ten measurements of the maxillary intercanine distance from three samples of each wax; each of the ten measurements were made at least twenty four hours apart. Overjet measurement error was determined for the bite sticks by making ten overjet measurements from three different bite sticks and from three Aluwax bites with each of the ten measurements being made at least twenty four hours apart. The intraclass correlation coefficients for each type of wax tested as well as for both the bite stick and wax overjet measurements ranged from 0.99 to 1.00.

Results of this pilot investigation are detailed in Appendix 1 and summarized in Tables 1, 2, 3 and 4 with an overall finding that the Aluwax bite exhibited the best accuracy and durability for use in detecting occlusal relationships which would indicate moderate to severe post-operative change in a patient's occlusion. Measurements of intra-arch distance between various dental landmarks demonstrated that wax #1 showed significantly smaller posterior intraarch dimensions than were actually present for one of the test subjects. This wax was thus determined to be less durable than the other two waxes tested. The Aluwax bite demonstrated an approximate 50% reduction in

the degree of discrepancy between the model measurements and the measurements from wax #2, with an average difference of 0.4 mm.

Each wax sample was also evaluated for the presence of any open bite and/or cross bite which could indicate improper occlusal recordings, i.e., not biting into centric occlusion. One test subject demonstrated some type of open bite on each of the three samples of wax #1 where no open bite actually existed, demonstrating an inability to accurately mark centric occlusion easily with this particular wax. All other wax samples, twenty six in all, gave accurate centric occlusion recordings.

The bite stick overjet measurements averaged 0.575 mm greater than the overjets measured from the mounted models. These measured mean differences ranged from 0.1 mm to 1.0 mm while the difference between any individual bite stick measurement and its comparable model measurement ranged from -1.9 mm to +2.5 mm; twenty nine bite stick measurements were greater than their comparable model overjet measurement, seven were lower and two were the same as the overjet measured off the model.

Overjet was also measured off the Aluwax bite registration and these averaged 0.15 mm of difference from the model overjet measurements. The measured mean differences ranged from 0.1 mm to 0.2 mm while the

difference between any single wax bite measurement and its comparable model measurement ranged from -0.3 mm to +0.3 mm. Four wax overjet measurements were greater than their comparable model overjet measurement, nine were lower and one was the same as the overjet measured off the model. Clearly, the Aluwax bite registrations more accurately approximated the overjets obtained from the mounted models than the bite sticks. Nevertheless, inclusion of the bite sticks in a packet of materials to screen for moderate to severe occlusal change after orthodontics and orthognathic surgery was deemed appropriate as a check against the possibility that a patient with a very flat curve of Spee or an anterior open bite would register their bite in a forward mandibular position, a situation in which the determination of an accurate centric occlusion registration might be equivocal from the wax alone.

Table 1.--Mean Wax Bite Measurements

Landmarks	Model (mm)	Wax #1 (mm)	Wax #2 (mm)	Wax #3 (mm)
U3 - 3 Cusp tip	34.25	33.68	35.03	34.53
U6 - 6 MB Cusp tip	48.98	47.38	47.83	49.33
U6 - 6 Central groove	44.35	42.78	45.73	45.15
U6 - 6 ML Cusp tip	37.25	35.58	37.15	37.50
L6 - 6 MB Cusp tip	42.68	42.15	43.58	43.20
L6 - 6 Central groove	39.53	38.78	39.90	39.73

Table 2.--Mean Difference between Model Measurements and Wax Bite Measurements

Landmarks	Wax #1 (mm)	Wax #2 (mm)	Wax #3 (mm)
U3 - 3 Cusp tip	.57	.78	.28
U6 - 6 MB Cusp tip	1.60	1.15	.35
U6 - 6 Central groove	1.57	1.38	.80
U6 - 6 ML Cusp tip	1.67	.10	.25
L6 - 6 MB Cusp tip	.53	.90	.52
L6 - 6 Central groove	.75	.37	.20
All landmark measurements	1.12	.78	.40

Table 3.--Overjet Measurements from Bite Sticks

Patient	Model (mm)	Mean Bite Stick (mm)	Difference (mm)
1	2.1	3.1	1.0
2	0.5	1.1	0.6
3	3.2	3.8	0.6
4	2.1	2.0	0.1
Mean			0.575

Table 4.--Overjet Measurements from Aluwax

Patient	Model (mm)	Mean Aluwax (mm)	Difference (mm)
1	2.1	2.0	0.1
2	0.5	0.7	0.2
3	3.2	3.1	0.1
4	2.1	1.9	0.2
Mean			0.15

Prevalence Study

The principal investigator obtained the names, demographic data and operative notes of 294 patients who

met the study criteria randomly chosen from a comprehensive list of all orthognathic surgery patients treated during the 1980s in the two aformentioned surgical practices. A minimum of five attempts to contact each patient by phone were made and, if unsuccessful, a minimum of five attempts were made to contact the parents of the patient in order to secure a recent telephone number. If a new number was obtained, a minimum of five attempts to contact the patient were once again made. One hundred forty seven people were ultimately contacted with one of these persons choosing not to participate in the study. One hundred forty six people who, during the initial telephone conversation, consented to participate in the study were sent a packet of materials which included a cover letter, an informed consent form, a two-page questionnaire, two wax bite registrations, two overjet registration sticks, written directions for completing the wax bites and overjet registrations, a pencil, a retainer case in which to place the completed wax bites and a pre-addressed and stamped padded mailer in which to return all of the materials (see Appendix 2). Follow-up phone calls and letters were used to secure the return of as many packets as possible. Three people were either unwilling or unable to further participate in the study when contacted during the follow-up telephone calls: one patient simply choose not to participate at that time,

one person was dead and one person refused to fill out a second packet of materials after the first packet was not received by the principal investigator. In the end, one hundred thirty two of those persons who had initially agreed to participate in the study returned their packets by February 1, 1996 and were included as part of the study sample. Eleven people did not return their study materials eventhough they had given verbal consent and been contacted numerous times on follow-up. Thus, 50% of the random sample of patients from the two practices were able to be personally contacted and, of these, 99.3% initially agreed to participate in the study though this decreased during the course of the investigation to 97.3% of those contacted. In the end, 92.3% of those people who agreed to participate in the study returned their packets for evaluation.

For purposes of this study, moderate to severe occlusal change was said to be present if any one of the following criteria was assessed from the self-administered wax bite and/or bite stick: any anterior open bite; complete unilateral or bilateral posterior open bite; any posterior crossbite; any overjet of five millimeters or greater; or any negative overjet. Overjet was determined via two methods, the first being the average of each bite stick measurement as taken from the center of each bite

stick mark and the second being the average of each wax bite overjet as taken from the point of greatest overjet between the maxillary central incisors and mandibular incisors (see Figures 1 and 2).

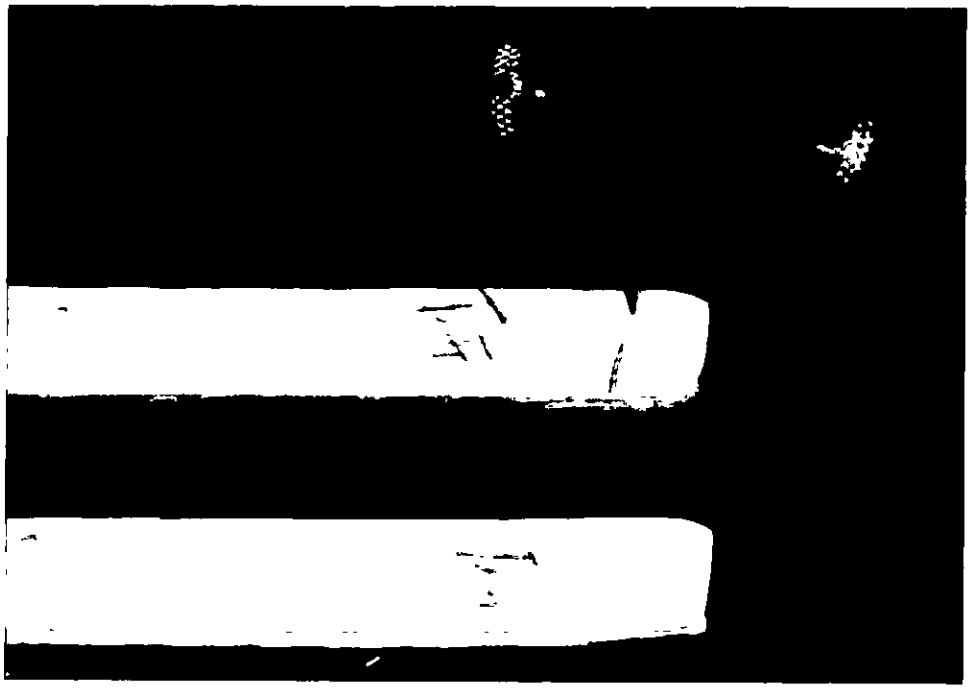


Figure 1. Measurement of a bite-stick for overjet determination



Figure 2. Measurement of a wax bite for overjet determination

Both average bite stick overjet value and average wax bite overjet value must have been greater than five millimeters to be considered a positive criteria for moderate to severe occlusal change, with the realization that normal overjet is considered to be one to one and one half millimeters. The principal investigator evaluated all of the returned wax bites for probable accuracy based upon the presence of posterior maximal interdigitation and the coincidence between the overjets measured from the wax bites and those measured from the bite sticks. The principal investigator

made all measurements with a Helios gauge, rounding each measurement to the nearest tenth of a millimeter.

Data Analysis

All outcome variables were measured as dichotomous and if any one of these variables was present, the patient was considered to have undergone moderate to severe occlusal change. The data was further evaluated by frequency determination of the following stratification variables: gender, age at the time of surgery, pre-operative maxillo-mandibular relationship, surgical procedure, fixation technique, surgeon, orthodontist and pre-operative temporomandibular joint pathology.

RESULTS

Resultant Sample

One hundred thirty two subjects returned wax bites and bite sticks for inclusion in the study of which all but two were judged acceptable for evaluation. The wax bites of the two subjects which were determined to be unacceptable for evaluation appeared to be taken in a mandible-advanced position, demonstrating a significantly smaller overjet than that shown on the corresponding bite sticks. Both subjects were contacted and the principal investigator subsequently met with each of the subjects and obtained an accurate wax bite and overjet measurement.

One hundred thirty two subjects, then, constituted the study sample for this investigation, of which 103 (78%) were female and 29 (22%) were male. The average age at the time of surgery was 25.7 years with the males averaging 26.7 years and the females averaging 25.4 years. Age distribution for the males was from 15.11 years to 51.10 years and the distribution for the females was 14.4 years to 45.8 years.

There are a wide variety of pre-operative diagnoses

represented in the resultant sample. Twenty nine people had a diagnosis of mandibular prognathia prior to surgery. A variety of concomitant diagnoses were seen including maxillary hypoplasia, maxillary hyperplasia with or without a concomitant apertognathia, maxillary retrognathia with or without a concomitant apertognathia, lateral asymmetry, focal maxillary hypoplasia and/or internal derangement of their temporomandibular joints. Table 5 summarizes this data on the mandibular prognathic subjects.

Table 5.--Subjects with the Pre-operative Diagnosis of Mandibular Prognathia

Diagnosis	Subjects
Mandibular prognathia only	19
Mand prog with internal TM joint derangement	1
Mand prog with lateral asymmetry	1
Mand prog with focal maxillary hypoplasia	1
Mand prog with maxillary hypoplasia	3
Mand prog with maxillary hyperplasia	1
Mand prog with maxillary hyperplasia & apertognathia	1
Mand prog with maxillary retrognathia	1
Mand prog with maxillary retrognathia & apertognathia	1
Total	29

Mandibular retrognathia or hypoplasia was a pre-operative diagnosis for ninety patients. A variety of concomitant diagnoses were also present and these are detailed in Table 6.

Table 6.--Subjects with a Pre-operative Diagnosis of Mandibular Retrognathia or Hypoplasia

Diagnosis	Subjects
Mandibular retrognathia alone	45
Mand retro with maxillary hyperplasia	9
Mand retro with maxillary hyperplasia and apertognathia	7
Mand retro with apertognathia	1
Mand retro with maxillary constriction	4
Mand retro with max constriction and max hyperplasia	2
Mand retro with TM pathology	9
Mand retro with TM pathology and apertognathia	1
Mand retro with TM pathology and max hyperplasia	1
Mand retro with TM pathology, max hyperplasia and apertognathia	3
Mand retro with TM pathology and laterognathia	1
Mand retro with TM pathology, laterognathia and apertognathia	1
Mand retro with laterognathia, max hyperplasia and maxillary prognathia	1
Mand retro with max hyperplasia and a nasal deformity	3
Mand retro with vertical mandibular deficiency	1
Mand retro with max hypoplasia, VME, apertognathia and max constriction	1
Total	90

Vertical maxillary excess was seen pre-operatively in thirty four patients. Vertical maxillary excess with no concomitant mandibular diagnosis was seen in five patients with one of these having a nasal deformity accompanying the maxillary excess. The remaining twenty nine subjects had a concomitant mandibular diagnosis. Various other diagnoses were present in this group as well which are detailed in Table 7.

Table 7.--Subjects with a Pre-operative Diagnosis of Vertical Maxillary Excess

Diagnosis	Subjects
Vertical maxillary excess	4
Vertical maxillary excess with nasal deformity	1
VME with mandibular retrognathia	9
VME with mand retrognathia and maxillary constriction	2
VME with mand retrognathia and TM pathology	2
VME with mand retrognathia and nasal deformity	4
VME with mand retrognathia and laterognathia	1
VME with mand retrognathia and apertognathia	5
VME with mand retrognathia, apertognathia and TM pathology	3
VME with mand retrognathia, apertognathia and nasal deformity	2
VME with mandibular prognathia and apertognathia	1
Total	34

Ten patients had a pre-operative diagnosis of maxillary transverse constriction although only two patients were treated for this diagnosis alone. This data is detailed in Table 8.

Table 8.--Subjects with a Pre-Operative Diagnosis of Maxillary Constriction

Diagnosis	Subjects
Maxillary constriction alone	2
Max constriction and mandibular retrognathia	4
Max constriction, mand retrognathia and VME	2
Max constriction, mand retrognathia, maxillary hypoplasia and apertognathia	1
Max constriction and apertognathia	1
Total	10

Twelve subjects had a pre-operative diagnosis which included maxillary hypoplasia or maxillary retrognathia of which two had simply maxillary hypoplasia and one had only

maxillary retrognathia. Details of the full diagnoses of the patients in this group are summarized in Table 9.

Table 9.--Subjects with the Pre-operative Diagnosis of Maxillary Hypoplasia or Maxillary Retrognathia

Diagnosis	Subjects
Maxillary hypoplasia alone	2
Maxillary retrognathia alone	1
Maxillary retrognathia with mandibular prognathia	1
Maxillary retrognathia with mandibular prognathia and apertognathia	1
Maxillary hypoplasia with mandibular prognathia	4
Focal maxillary hypoplasia with mandibular prognathia	1
Maxillary hypoplasia with bimalar hypoplasia	1
Maxillary hypoplasia with maxillary constriction, mandibular retrognathia and apertognathia	1
Total	12

Sixteen subjects had a pre-operative diagnosis of apertognathia, all of which had concomitant pre-operative diagnoses. Mandibular retrognathia was also diagnosed in one person while mandibular retrognathia and temporomandibular joint pathology was diagnosed along with the apertognathia in one other patient. Mandibular retrognathia with vertical maxillary excess were concomitant diagnoses in seven patients and mandibular retrognathia with vertical maxillary excess and temporomandibular pathology were concomitant in three patients. Two patients with open bite also had mandibular prognathia, one with vertical maxillary hyperplasia and one with maxillary retrognathia. One patient had a group of

diagnoses including open bite, mandibular retrognathia, laterognathia and temporomandibular pathology while another patient had open bite, maxillary hypoplasia, maxillary constriction and mandibular retrognathia. This data is detailed in Table 10.

Table 10.--Subjects with a Pre-operative Diagnosis of Apertognathia

Diagnosis	Subjects
Apertognathia with mandibular retrognathia	1
Apertognathia with mandibular retrognathia and TM pathology	1
Apertognathia with mandibular retrognathia and VME	7
Apertognathia with mandibular retrognathia, VME and TM pathology	3
Apertognathia with mandibular retrognathia, laterognathia and TM pathology	1
Apertognathia with mandibular retrognathia, maxillary hypoplasia and maxillary constriction	1
Apertognathia with mandibular prognathia and maxillary hyperplasia	1
Apertognathia with mandibular prognathia and maxillary retrognathia	1
Total	16

The variety of pre-operative diagnoses seen within the resultant sample also included mandibular asymmetry in one patient while maxillary prognathism was the diagnosis of two others.

Table 11 summarizes the number of subjects within each major category of pre-operative diagnosis: mandibular retrognathia, mandibular prognathia, vertical maxillary excess, maxillary hypoplasia including maxillary retrognathia, focal maxillary hypoplasia, maxillary

constriction, maxillary prognathia, apertognathia, laterognathia, temporomandibular joint pathology, nasal deformity, mandibular asymmetry and mandibular vertical deformity.

Table 11.--Summary of Pre-operative Diagnoses

Diagnosis	Subjects
Mandibular retrognathia	90
Mandibular prognathia	29
Vertical maxillary excess	34
Maxillary hypoplasia or retrognathia	12
Maxillary constriction	10
Apertognathia	16
Laterognathia	4
Temporomandibular pathology	16
Nasal deformity	5
Mandibular asymmetry	1
Maxillary prognathia	2
Mandibular vertical deformity	1

Each patient in the resultant sample was from one of two oral and maxillofacial surgery practices. Seventy subjects in the resultant sample are from one practice while sixty two subjects in the resultant sample are from the second practice.

Thirty two different practices were responsible for the orthodontic component of treatment for the resultant sample. The number of resultant sample cases in any given orthodontic practice ranged from one to twenty three. Table 12 delineates the number of resultant sample cases treated orthodontically in each of the thirty two practices represented in this investigation.

Table 12.--Cases per Orthodontic Practice

Ortho practice	Cases	Ortho	Cases	Ortho	Cases
i	9	xii	11	xxiii	1
ii	11	xiii	1	xxiv	3
iii	2	xiv	3	xxv	1
iv	1	xv	1	xxvi	1
v	23	xvi	2	xxvii	1
vi	4	xvii	3	xxviii	1
vii	4	xviii	2	xxix	1
viii	10	xvix	1	xxx	1
ix	6	xx	2	xxxi	1
x	10	xxi	2	xxxii	1
xi	1	xxii	1		
				Total 32	132

A variety of surgeries were performed on the patients in the resultant sample. Mandibular prognathia was treated with either intraoral vertical ramus osteotomies, bilateral sagittal split osteotomies or inverted-L osteotomies. Sixteen intraoral vertical ramus osteotomies were performed on patients of the resultant sample. Twelve sagittal split osteotomies were performed and one inverted-L osteotomy was performed. Two patients required subsequent retreatment, one having had a sagittal split osteotomy and the other having had the inverted-L osteotomy; both were retreated with a multi-piece Le Fort I. One vertical ramus osteotomy was performed concomitant with infraorbital hydroxyapatite implants, another was performed along with the placement of lateral nasal proplast implants and two were performed concomitant with maxillary proplast implants. The inverted-L osteotomy was performed concurrent with the

placement of maxillary proplast implants. Table 13 summarizes the data on the treatment of mandibular prognathism.

Table 13.--Surgical Treatment for Mandibular Prognathia

Surgery	Rigid Fixation	IMF
Internal vertical ramus osteotomies alone	2	9
IVRO with infraorbital HA implants	1	
IVRO with maxillary proplast implant(s)		2
IVRO with lateral nasal proplast implants		1
IVRO with LeFort I osteotomy	1	
Bilateral sagittal split osteotomies alone	2*	8
BSSO with LeFort I osteotomy	2	
Inv-L with maxillary proplast implant(s)		1*
Total IVROs	4	12
Total BSSOs	4	8
Total Inverted-L		1
Total surgeries for mandibular prognathia	8	21

* case (one of the group) required retreatment at a later date

Within the resultant sample, the surgical treatment of retrognathia depended primarily on the sagittal split osteotomy, though not exclusively. Forty five cases were treated with a sagittal split osteotomy alone. Ten cases were treated with sagittal split osteotomies and a concomitant genioplasty with one of these cases also having a concomitant mandibular anterior vertical osteotomy. Sixteen patients had sagittal split osteotomies along with a Le Fort I osteotomy while ten cases were treated with sagittal split osteotomies, a Le Fort I

osteotomy and genioplasty. Five patients were treated with a Le Fort I and genioplasty and one case underwent a Le Fort I osteotomy and an extraoral inverted-L osteotomy with hip grafts. The data describing the surgical treatment of mandibular retrognathia of the resultant sample is detailed in Table 14.

Table 14.--Surgical Treatment for Mandibular Retrognathia

Surgery	Rigid Fixation	IMF
Bilateral sagittal split osteotomies	30	15
BSSO with genioplasty	3	2
BSSO with segmental osteotomy and genioplasty		1
BSSO with bone graft and genioplasty	1	
BSSO with TMJ surgery and genioplasty	3	
BSSO with LeFort I	10*	3
BSSO, LeFort I and TMJ procedure		1
BSSO, LeFort I and nasal procedure	1	
BSSO, LeFort I and genioplasty	8	
BSSO with suprahyoid myotomy, LeFort I and genioplasty	1	
BSSO, LeFort I, genioplasty and TMJ procedure		1
LeFort I and genioplasty	1	
LeFort I, genioplasty, and nasal procedure	2	1
LeFort I	1	
LeFort I and TMJ procedure		1
LeFort I and nasal procedure	1	
Extraoral inverted-L osteotomy with hip graft and LeFort I	1	
Total BSSO	30	15
Total BSSO with genioplasty	7	5
Total BSSO with LeFort I	11	5
Total BSSO, LeFort I and genioplasty	9	1
Total LeFort I and genioplasty	3	2
Total LeFort I	2	1
Total extraoral inverted-L and LeFort I		1

* 1 case re-surgerized 2 months later

Vertical maxillary excess was treated with Le Fort I osteotomies exclusively, though numerous procedures were performed concomitantly to correct other maxillofacial concerns. Only four single Le Fort I osteotomies were performed. Two Le Fort I osteotomies were performed with adjunctive nasal procedures, one Le Fort I was performed with a concomitant temporomandibular joint procedure, two were performed with genioplasty and three were performed with genioplasty and a nasal procedure. Twelve Le Fort I osteotomies concurrent with bilateral sagittal split osteotomies were performed, one of which necessitated resurgery fifty seven days post-operatively. Six cases were treated with a Le Fort I, sagittal split and genioplasty while two cases were treated with a Le Fort I, sagittal split and a nasal procedure. Finally, one Le Fort I osteotomy was performed in addition to an extra-oral inverted-L osteotomy with hip grafts. This data is summarized in Table 15.

Table 15.--Surgical Treatment of Vertical Maxillary Excess

Surgery	Rigid	IMF
LeFort I osteotomy	2	2
LeFort I osteotomy with nasal procedure	2	
LeFort I osteotomy with TMJ procedure		1
LeFort I osteotomy with genioplasty	1	1
LeFort I, genioplasty and nasal procedure	1	2
LeFort I and bilateral sagittal split osteotomy	9*	3
LeFort I, BSSO and nasal procedure	1	1
LeFort I, BSSO and TMJ procedure		1
LeFort I, BSSO and genioplasty	6	
LeFort I and extra-oral inverted-L osteotomy with hip grafts	1	
Total LeFort I	23	11

* one case was re-surgerized 57 days later

The surgical treatment of maxillary hypoplasia or maxillary retrognathia in the resultant sample relied primarily on the Le Fort I osteotomy, isolated proplast onlay grafts or some combination of the two. Two patients had a singular diagnosis of maxillary hypoplasia and were treated with a Le Fort I osteotomy, one being a two piece and the other a three piece osteotomy; one patient with the singular diagnosis of mandibular retrognathia was treated with a one piece Le Fort I. Four patients had pre-operative diagnoses of maxillary hypoplasia with mandibular prognathism; three were treated with vertical ramus osteotomies and maxillary onlay implants while the third was treated with an inverted-L osteotomy and maxillary onlay implants. This latter case required retreatment six

years and seven months later and was treated at that time with a three piece Le Fort I osteotomy. One case diagnosed as maxillary retrognathia and mandibular prognathia was treated with a one piece Le Fort I and vertical ramus osteotomies while another case diagnosed as focal maxillary hypoplasia and mandibular prognathia was treated with vertical ramus osteotomies and lateral nasal implants. Maxillary hypoplasia with bimalar hypoplasia was the diagnosis for one case treated with a Le Fort I osteotomy, genioplasty and infra-orbital proplast implants. Finally, there were two cases that included a diagnosis of open bite. The first case had a combined diagnosis of maxillary hypoplasia, maxillary constriction, mandibular retrognathia and apertognathia which was treated with a three piece Le Fort I and sagittal split osteotomies. The second case was diagnosed as maxillary retrognathia, mandibular prognathia and apertognathia which was treated with a single piece Le Fort I, a sagittal split osteotomy and genioplasty but which required retreatment one year and six months later with a two piece Le Fort I for maxillary constriction and apertognathia. This information is summarized in Table 16.

Table 16.--Surgical Treatment of Maxillary Hypoplasia and Maxillary Retrognathia

Dx	Surgery	Rigid	IMF
Mx hypopl	2-piece LeFort I osteotomy	1	
	3-piece LeFort I osteotomy	1	
Mx hypopl Mnd prog	IVRO, focal maxillary onlays	1	2
Mx hypopl Mnd prog	Inverted-L osteotomy, focal maxillary onlays	1*	
Mx hypopl Bimalar hypopl	LeFort I, infra-orbital onlays, genioplasty	1	
Focal max hypopl, Mnd prog	IVRO, lateral nasal onlay		1
Mx hypopl, Mx constrict, Mnd retro, Apertognathia	3-piece LeFort I, BSSO	1	
Max retro	LeFort I		1
Max retro Mnd prog	LeFort I, IVRO	1	
Max retro Mnd prog Apertognathia	LeFort I, BSSO, genioplasty	1**	

* retreated with 3-piece LeFort I 6.7 years later
** retreated with 2-piece LeFort I 1.6 years later

Ten patients in the resultant sample had a pre-operative diagnosis that included maxillary constriction. Eight of the ten patients were treated for the maxillary constriction with a two piece Le Fort I while the two other cases were treated with a three piece Le Fort I. One of the two piece Le Fort I osteotomies was a surgical retreatment with a diagnosis of maxillary constriction and apertognathia after having been treated one year and six

months earlier with a single piece Le Fort I for the diagnosis of maxillary retrognathia and apertognathia. This data is summarized in Table 17.

Table 17.--Surgical Treatment of Maxillary Constriction

Surgery	Rigid Fixation	IMF
2 piece LeFort I osteotomy	6*	2
3 piece LeFort I osteotomy	2	
Total	8	2

* one case was a surgical retreatment of a surgical case treated 1.6 years earlier

Sixteen patients in the resultant sample had a pre-operative diagnosis which included apertognathia. Fourteen of these cases were treated with single or multi-segment Le Fort I osteotomies and eleven of these cases included a sagittal split osteotomy while one included an extraoral inverted-L osteotomy for treatment of the mandibular component of the maxillomandibular malrelation. Two cases, one with the combined diagnosis of mandibular retrognathia, laterognathia, apertognathia and temporomandibular pathology and the second with the diagnoses of mandibular retrognathia, apertognathia and temporomandibular pathology were treated with mandibular procedures alone. The former case was treated with a sagittal split osteotomy, genioplasty and bone graft while the latter was treated

with a sagittal split osteotomy and a mandibular anterior segmental osteotomy. Table 18 summarizes the treatment of open bite in the resultant sample.

Table 18.--Surgical Treatment for Apertognathia

Surgery	Rigid Fixation	IMF
1 piece LeFort I	1	1
1 piece LeFort I and BSSO	7*	1
2 piece LeFort I and BSSO	1	1
3 piece LeFort I and BSSO	1	
3 piece LeFort I and extraoral inverted-L	1	
BSSO	1	
BSSO and mandibular anterior segmental		1

* one case was retreated 1.6 years later for maxillary constriction and apertognathia with a 2 piece LeFort I

Four cases in the resultant sample had the diagnosis of laterognathia along with other concomitant diagnoses. In all four cases, the surgical treatment of choice was made based upon a more primary diagnosis, for instance mandibular retrognathia or vertical maxillary excess. In only one case was a two jaw surgical procedure performed. Table 19 summarizes the surgical treatment performed on patients with a diagnosis that included laterognathia.

Table 19.--Surgical Treatment for Laterognathia

Diagnosis	Surgery	Rigid Fixation	IMF
Mnd retrognathia, Laterognathia, Apertognathia, TM dysfunction	BSSO, genioplasty with bone graft	1	
Mnd prognathia L laterognathia	IVRO		1
Mnd retrognathia, Mnd R laterognathia, Max L laterognathia, Max L vert hyperplasia, Bilateral dislocated discs	2 piece LeFort I, bilateral arthroscopy with tendon release		1
Max posterior excess, Max prognathia, Mnd retrognathia, Laterognathia	LeFort I, BSSO	1	

Sixteen patients within the resultant sample had a pre-operative diagnosis which included some type of temporomandibular pathology. Five of these patients received some type of specific surgical intervention into the temporomandibular joint complex concomitant with an orthognathic procedure and all five of these patients came from the same oral and maxillofacial surgical practice. The other ten patients did not receive concomitant temporomandibular joint surgery along with their orthognathic surgery and these cases were distributed between the two oral and maxillofacial surgery practices with three being from one practice and seven from another. One patient had received temporomandibular joint surgery

one year prior to their orthognathic procedure and this joint surgery was performed concomitant with a surgically assisted palatal expansion. Three years earlier, this patient had been seen in another state for "TMJ syndrome" and had undergone a mandibular advancement from which she subsequently relapsed. Fifteen of the cases had a concomitant diagnosis of mandibular retrognathia and one had a concomitant diagnosis of mandibular prognathia while five had a concomitant diagnosis of apertognathia. The details of those cases with a pre-operative diagnosis of temporomandibular pathology and who had subsequent temporomandibular joint surgery are summarized in Table 20 while those cases that did not have temporomandibular joint surgery are summarized in Table 21.

Table 20.--TMJ and Orthognathic Surgeries for Cases with a Pre-operative Diagnosis of Temporomandibular Pathology

Diagnosis	Surgery	Rigid Fixation	IMF	OMS Practice
Mnd retrognathia, TM dysfunction with closed lock	LeFort I, BSSO, genioplasty, bilateral arthroplasties meniscus repairs and dermal grafts		1	a
Mnd retrognathia, Laterognathia, Bilateral dislocated discs	2 piece LF I, bilateral arthroscopy with tendon release		1	a
Mnd retrognathia, Bilateral TM internal derangements	BSSO, genioplasty, bilateral arthroscopy	1		a
Mnd retrognathia, VME Anterior displaced discs	LeFort I, BSSO, bilateral arthroplasty with meniscus repairs		1	a
Mnd retrognathia, bilateral dislocated discs	BSSO, genioplasty bilateral arthroscopy and disc repositioning	1		a

Table 21.--Orthognathic Surgeries for Cases with a Pre-operative Diagnosis of Temporomandibular Pathology

Diagnosis	Surgery	Rigid Fixation	IMF	OMS Practice
Mnd prognathia, bilateral TM derangement	IVRO		1	b
Mnd retrognathia, bilateral TM derangement	BSSO		1	b
VME, apertognathia, mnd retrognathia, TM dysfunction	LeFort I, genioplasty		1	b
Mnd retrognathia, apertognathia, TM dysfunction	BSSO, mnd anterior segmental		1	b
Mnd retrognathia, laterognathia, apertognathia, TM dysfunction	BSSO, genioplasty with bone grafts	1		b
VME, apertognathia, mnd retrognathia, TM intl derangmnt	BSSO, LeFort I	1		a
VME, apertognathia, mnd retrognathia, severe bilateral condylar resorptn	3 piece LF I, extraoral inverted-L with hip grafts	1		a
Mnd retrognathia, TM dysfunction	BSSO	1		b
Mnd retrognathia, TM dysfunction	BSSO	1		a
Mnd retrognathia, TM dysfunction	BSSO		1	b
VME, mnd retrognathia, TMJ derangements, s/p mnd advncmnt 4.4 yrs earlier	LeFort I, BSSO	1		a
-1 yr earlier-				
VME, mnd retrognathia, max constriction, TMJ derangements, s/p mnd advncmnt 3.4 yrs earlier	Surg-assisted RPE, bilateral arthroplasty, disc repairs & dermal grafts			

Five patients in the resultant sample had a nasal deformity diagnosed along with other maxillomandibular diagnoses which, in all cases, included vertical maxillary excess. All five cases had specific nasal procedures performed concomitant with a single or multiple piece Le Fort I osteotomy and all five cases were from the same oral and maxillofacial surgery practice. Table 22 summarizes the information on those cases in which a nasal deformity was diagnosed and treated.

Table 22.--Surgical Treatment of Nasal Deformity

Diagnosis	Surgery	Rigid Fixation	IMF	OMS Practice
VME, mnd retrognathia, septal deviation	LeFort I, BSSO, septoplasty	1		b
VME, mnd retrognathia	2 piece LF I, genioplasty, septoplasty		1	b
VME, mnd retrognathia	LeFort I, genioplasty, turbinate outfractures	1		b
VME	LeFort I, lateral turbinectomies, septoplasty	1		b
VME, mnd retrognathia, septal deviation	2 piece LF I, genioplasty, turbinectomies, nasal reconstrctn	1		b

One case in the resultant sample had a pre-operative diagnosis of mandibular asymmetry. This asymmetry was

secondary to a previous mandibular fracture and was treated with a sagittal split osteotomy with concomitant genioplasty.

Maxillary prognathia was a pre-operative diagnosis in two cases within the resultant sample. In one case, it was the lone diagnosis and was treated with a maxillary anterior segmental set-back with concurrent extraction of the maxillary first bicuspids. In the second case, the diagnosis of maxillary prognathism was concurrent with the diagnosis of maxillary posterior excess, mandibular retrognathia and laterognathia which was treated with a Le Fort I osteotomy and sagittal split osteotomy.

One case in the resultant sample had a pre-operative diagnosis of a mandibular vertical deficiency which was concomitant with the diagnosis of mandibular retrognathia. The vertical deficiency was corrected with a genioplasty which was performed with a sagittal split osteotomy for the correction of the antero-posterior problem.

The dates of surgery of the cases in the resultant sample range from February 14, 1980 to December 15, 1989. Follow-up ranges, therefore, are 15.11 years to 6.1 years with an average of 9.3 years.

Overjet measurements, the presence or absence of an overbite and/or posterior crossbite, canine relationship, preoperative diagnosis, surgery, fixation method and

follow-up period are detailed for each of the one hundred thirty two respondents in Appendix 3.

Relapse Data

The determination of significant occlusal change in this study was based on a positive finding from any one of five criteria previously defined as indicating moderate to severe significant occlusal change. The findings from the assessment of each criterion will be presented and discussed separately.

In many places throughout this section on the presentation of data, the word "relapse" is used in lieu of the phrase "significant occlusal change" in an effort to provide some syntactical harmony to those situations when the use of "significant occlusal change" seemed cumbersome. Thus, whenever primary data is presented from this investigation and termed "relapse", it simply connotes significant, post-operative occlusal change as defined by the parameters measured in the course of this investigation.

Anterior Open Bite

Twelve subjects (9.09%) were found to have an anterior open bite on wax bite evaluation. Three of these open bite

cases had a positive incisal overlap eventhough the maxillary anterior teeth did not occlude with the mandibular anterior teeth while the other nine cases were absolute vertical open bites.

Eleven of the twelve open bite patients are female (92%). The average age at the time of surgery for all of the open bite patients was 23.9 years with the average age of the females being 24.3 years (range of 14.7 years to 44.6 years) and the average age of the male being 18.5 years.

Four of the twelve (33.3%) post-operative open bite patients were treated in one surgical practice while the remaining eight, or 66.7%, were treated in the second surgical practice represented in this investigation.

Ten different orthodontic practices treated those patients who had a long-term post-operative open bite. Eight orthodontic practices treated one post-operative open bite patient each and two practices treated two post-operative open bite patients each.

Those cases demonstrating a long-term post-operative open bite had a variety of pre-operative diagnoses and subsequent surgical interventions, though it is interesting that all but one of the long-term post-operative open bite patients underwent either a single or multiple piece Le Fort I osteotomy for a variety of maxillary diagnoses; only

two of the twelve patients had a mandibular diagnosis alone, that of mandibular retrognathia, and even one of those was treated with a Le Fort I osteotomy as well as the standard sagittal split osteotomy. Only two of the twelve post-operative open bite patients had a pre-operative diagnosis of some type of temporomandibular joint pathology and one of these patients had a pre-operative diagnosis of severe condylar resorption. In relative terms those with a post-operative open bite were only slightly more likely to have a temporomandibular joint pathology (16.7%) than the non-postoperative open bite patients (13.3%). Three of the open bite patients had a pre-operative diagnosis of maxillary constriction (25%) compared to seven patients with a pre-operative diagnosis of maxillary constriction that did not have a post-operative open bite (5.8%). Table 23 summarizes the pre-operative diagnoses, surgical treatment and fixation method for those patients with a post-operative open bite.

Table 23.--Pre-operative Diagnosis, Surgical Treatment and Fixation Method for Post-operative Open Bite Patients

Diagnosis	Surgery	Rigid Fixation	IMF
Mnd retrognathia	BSSO	1	
Mnd retrognathia, TMJ dysfunction with closed lock	LF 1, BSSO, genio, bilateral arthroplasties, meniscus repairs & dermal grafts		1
VME	Le Fort I	1	
VME, mnd retrognathia	LF I, BSSO	1	
VME, mnd retrognathia	2 piece LF I, BSSO, genio	1	
VME, mnd retrognathia, nasal deformity	LF I, BSSO, septoplasty	1	
VME, mnd retrognathia, max transverse def	3 piece LF I, genio	1	
VME, mnd retrognathia, apertognathia	LF I, BSSO, genio	1	
VME, mnd retrognathia, apertognathia	2 piece LF 1, BSSO, genio	1	
VME, mnd retrognathia, severe condylar resorption	3 piece LF I, extraoral inverted-L with hip grafts	1	
Max constriction	2 piece LF I		1
1st Surgery: Max retrognathia, mnd prognathia, apertognathia	LF I, BSSO, genio	1	
-1.6 yrs later-			
2nd Surgery: Max constriction, apertognathia	2 piece LF I	1	

Though not considered in determination of those patients exhibiting significant, post-operative occlusal change, nine patients were found to have an end-to-end anterior occlusion in the vertical plane. Six of the nine vertically end-to-end occlusions had a pre-operative diagnosis of either mandibular prognathia or maxillary retrognathia/hypoplasia. The other three cases all had a pre-operative diagnosis of mandibular retrognathia with two of these three cases having concomitant diagnoses of vertical maxillary excess and apertognathia.

Posterior Open Bite

None of the one hundred thirty two cases in the resultant sample demonstrated a posterior open bite from the canine to first molar either unilaterally or bilaterally. Thus, no case was determined to exhibit moderate to severe occlusal change based on this criteria.

Posterior Crossbite

One case within the resultant sample exhibited a unilateral posterior crossbite of the maxillary right second bicuspid and first molar with the mandibular right second bicuspid and first molar. The corresponding teeth on the left side of the mouth exhibited a constriction of

the maxillary arch but without a frank crossbite. The pre-operative diagnosis of this case was maxillary transverse hypoplasia and mandibular retrognathia which was treated with a two piece Le Fort I, bilateral sagittal split osteotomy and genioplasty. The patient is male and was 18.7 years old at the time of surgery. He was treated by an orthodontist who had no other patients meeting any criteria for moderately severe significant occlusal change.

Overjet of 5 mm or Greater

Seven cases (5.3%) within the resultant sample exhibited an overjet of five millimeters or greater on both bite stick and wax bite evaluation. The overjet of each of these seven cases ranged from 5.0 mm to 8.45 mm with an average of 6.08 mm. This compares to the average overjet of the remaining 125 cases of 2.54 mm.

Three of the seven cases meeting the occlusal relapse criteria of five millimeters or greater of overjet also exhibited an anterior open bite. Five of the seven cases with excessive overjet are female (71.4%). The average age of these cases is 21.11 years. The average age of the women with excessive overjet at the time of surgery was 21.4 years and the average age of the men was 23.4 years.

Four of the seven excessive post-operative overjet patients were treated in one surgical practice (57.1%)

while the other three were treated in the second surgical practice (42.9%) represented in this investigation.

Six different orthodontic practices treated these patients with five orthodontic practices having treated one patient each and one orthodontic practice having treated two patients with significant occlusal change based upon this criterion.

The pre-operative diagnosis for the seven patients in this subset was varied. Three patients had a pre-operative diagnosis of mandibular retrognathia, three had a diagnosis of mandibular retrognathia and vertical maxillary excess, one of whom also had a septal deviation and one patient, who in fact also met the relapse criterion of post-operative open bite, had a diagnosis of maxillary retrognathia, mandibular prognathia and apertognathia.

The surgical treatment of the seven patients in this subset each involved a sagittal split osteotomy. Those three patients with the diagnosis of mandibular retrognthia underwent a sagittal split osteotomy as their only surgical procedure, the three patients with the diagnosis of vertical maxillary excess and mandibular retrognathia had undergone a one piece Le Fort I and a bilateral sagittal split osteotomy and the seventh patient with the diagnosis of maxillary retrognathia, mandibular prognathia and apertognathia underwent a one piece Le Fort I, sagittal

split and genioplasty which was resurgerized one year and six months later with a two piece Le Fort I for correction of maxillary constriction and apertognathia. The data describing pre-operative diagnosis, surgical treatment and fixation method is summarized in Table 24.

Table 24.--Pre-operative Diagnosis, Surgical Treatment and Fixation Method for Patients with a Post-operative Overjet of 5 mm or Greater

Diagnosis	Surgery	Rigid Fixation	IMF
Mnd retrognathia	BSSO		1
Mnd retrognathia	BSSO		1
Mnd retrognathia	BSSO	1	
Mnd retrognathia & VME	LF I, BSSO	1	
Mnd retrognathia & VME	LF I, BSSO	1	
Mnd retro, VME, nasal procedure	LF I, BSSO,	1	
Max retrognathia, mnd prognathia, apertognathia	LF I, BSSO, genio	1	
-1.6 yrs later-			
Max constriction, apertognathia	2 piece LF I	1	

Negative overjet

None of the 132 cases in the resultant sample exhibited a negative overjet although four cases did exhibit an overjet of 0 mm, i.e., end-to-end horizontal occlusion. The pre-operative diagnosis of two of these four patients was mandibular prognathism while the other two patients had a pre-operative diagnosis of maxillary hypoplasia or maxillary retrognathia.

Summary of relapse data

Seventeen of the one hundred thirty two subjects (12.9%) in the resultant sample met the criteria for moderate to severe significant occlusal change in this investigation. Fourteen of these seventeen subjects met one post-operative criterion, either an anterior open bite, posterior crossbite or an overjet greater than five millimeters, while three subjects met two criterion, an anterior open bite plus an overjet greater than five millimeters. A description of each of the relapse cases with regard to age, gender, surgical practice, orthodontic practice, pre-operative diagnosis, surgical treatment and fixation method, has been given.

Stratification

To further describe the group of cases that exhibited significant occlusal change, the data has, as a singular group, been stratified by gender, age at the time of surgery, pre-operative maxillomandibular relationship, surgical procedure, fixation technique, surgical practice, orthodontic practice and presence of a pre-operative temporomandibular joint diagnosis.

Females predominate in the occlusal relapse group by a ratio of 14:3 or 82.4% female and 17.6% male. This compares to the non-relapse group in which the female to

male ratio is 89:26 or 77.4% female and 22.6% male. Table 25 summarizes this data.

Table 25.--Gender Distribution of Relapse Patients vs. Non-relapse Patients

Gender	Relapse Patients (n)	(%)	Non-relapse Patients (n)	(%)
Female	14	82.4	89	77.4
Male	3	17.6	26	22.6
Total	17	100.00	115	100.0

Stratification of the occlusal relapse group by age shows that well over half of the cases with significant post-operative occlusal change are under twenty years old while only one third of the non-relapse cases are under the age of twenty years. In each decade after the teens the proportion of occlusal relapse patients is underrepresented as compared to non-relapse patients. This age stratification data is detailed in Table 26.

Table 26.--Age Distribution of Relapse Patients vs. Non-relapse Patients

Age	Relapse Patients (n)	(%)	Non-relapse Patients (n)	(%)
14-19*	10	58.83	39	33.91
20-29	4	23.53	33	28.69
30-39	2	11.76	34	29.57
40-49	1	5.88	8	6.96
50-59	0	0.00	1	0.87
Total	17	100.00	115	100.00
*14-15	3	17.65	15	13.04
16-17	4	23.53	15	13.04
18-19	3	17.65	9	7.83

Determination of pre-operative maxillomandibular relationships in a diverse group of patients has the potential of being a very arduous yet ultimately ambiguous task. The variety of nuances inherent in the anteroposterior, vertical and transverse interrelationship of the dental arches, equivocation in the determination of which arch and which dimension is "at fault" and the potential effect of orthodontic compensation prior to a surgical diagnosis ever being attempted are only a few of the more obvious factors that can impact on the determination of pre-operative maxillomandibular relationship. Historically, Angle classification has been commonly employed in this determination, no doubt due to its ease of use and universality of understanding. Unfortunately, the Angle classification has three fairly substantial drawbacks when one is interested in a combined orthodontic and surgical outcome. First of all, the Angle classification really only describes the dental relationship between the arches which may or may not accurately mimic the skeletal relationship, secondly it only classifies the relationship of the anteroposterior dimension of the dentition and thirdly, this relationship is only evaluated at the first molars. For these reasons, pre-operative maxillomandibular relationship will not be described in terms of Angle classification, but rather for

purposes of this discussion, in terms of key skeletal relationships in each of the three dimensions. Stratification of the pre-operative maxillomandibular relationship was done in three separate groups with a primary diagnosis being made, wherever possible, based upon the dimension under consideration. When a primary diagnosis could not be made that dealt with the dimension under consideration, the cases are listed with their primary pre-operative orthognathic diagnosis at the bottom of each table under the term "Other".

The horizontal maxillomandibular relationship is described as either mandibular retrognathia or mandibular prognathia for ease of reporting. Mandibular retrognathia, in this case, means that the mandibular skeletal base is posterior to its normal relationship with the maxillary skeletal base; it does not attempt to distinguish between a mandible that is aberrantly posterior or a maxilla that is aberrantly anterior. By the same token, mandibular prognathia is the term used to describe the situation where the mandibular skeletal base is forward of the normal relationship with the maxillary skeletal base.

Maxillary constriction has been used to describe the pre-operative transverse maxillomandibular relationship. It should provide some understanding of the relative importance of the transverse dimension in subsequent

occlusal relapse, realizing that maxillary constriction usually has the effect of opening the bite and may thus have a role to play in post-operative apertognathia.

Pre-operative vertical problems are described in terms of vertical maxillary excess since it is, by far, the most common diagnosis dealing with malrelationships in a vertical dimension. It should be kept in mind that the usual effect of vertical maxillary excess is a relative mandibular retrognathia and a potential opening of the anterior bite and thus may play a role in post-operative apertognathia and, possibly, excessive post-operative overjet.

Open bite is included in the description of the pre-operative maxillomandibular relationship wherever relevant eventhough it is impossible to determine whether or not an open bite is skeletal or dental in nature in this investigation. Nonetheless, open bite has historically been described as being the most difficult maxillomandibular problem to reliably correct and, thus, is critical to an understanding of significant post-operative occlusal change.

Table 27.--Pre-operative Maxillomandibular Relationship of Relapse Patients vs. Non-relapse Patients -Anteroposterior Perspective-

M/M relationship	Relapse Patients (n)	(%)	Non-relapse Patients (n)	(%)
Mnd retro without apertognathia	10	58.83	66	57.39
Mnd retro with apertognathia	4	23.53	11	9.56
Mnd prog without apertognathia	0	0.00	30	26.09
Mnd prog with apertognathia	0	0.00	1	0.87
Other:				
Max constriction alone	1	5.88	1	0.87
VME alone	1	5.88	4	3.48
Max constriction and VME	1	5.88	0	0.00
Max hypo alone	0	0.00	1	0.87
Mnd asymmetry alone	0	0.00	1	0.87
TOTAL	17	100.00	115	100.00

Table 28.--Pre-operative Maxillomandibular Relationship of Relapse Patients vs Non-relapse Patients -Vertical Perspective-

M/M relationship	Relapse Patients (n)	(%)	Nonrelapse Patients (n)	(%)
VME without apertognathia	6	35.30	17	14.78
VME with apertognathia	3	17.65	8	6.96
Other:				
Mnd prog	1	5.88	27	23.47
Mnd retro	6	35.29	57	49.57
Max hypo	0	0.00	3	2.61
Max constriction	1	5.88	1	0.87
Mnd asymmetry	0	0.00	1	0.87
Max prog	0	0.00	1	0.87
TOTAL	17	100.00	115	100.00

Table 29.--Pre-operative Maxillomandibular Relationship of Relapse patients vs. Non-relapse Patients -Transverse Perspective-

M/M relationship	Relapse Patients (n)	(%)	Non-relapse Patients (n)	(%)
Max constriction	4	23.53	6	5.22
Other:				
Mnd retro	5	29.41	53	46.09
VME & mnd retro	7	41.18	20	17.39
Mnd prog	0	0.00	27	23.47
VME	1	5.88	4	3.48
Max hypo	0	0.00	3	2.61
Mnd asymmetry	0	0.00	1	0.87
Max prog	0	0.00	1	0.87
TOTAL	17	100.00	115	100.00

Perusal of the data contained in Tables 27, 28 and 29 show a number of interesting findings. Each of the three dimensions involved in determination of maxillomandibular relationship appears to play a part in the tendency toward significant post-operative occlusal change. In the anteroposterior plane, mandibular retrognathia alone does not predispose a case to a relatively higher occlusal relapse tendency although mandibular retrognathia with an open bite is 2.5 times more common a pre-operative maxillomandibular diagnosis in the occlusal relapse group than in the non-relapse group. By the same token, in the vertical plane, vertical maxillary excess either with or without an open bite is 2.5 times more commonly seen as a pre-operative maxillomandibular relationship in the group with significant post-operative occlusal change than in the non-relapse group. Finally, in the transverse plane, maxillary constriction is 4.5 times more commonly seen in occlusal relapse patients than in non-relapse patients.

Stratification by surgical procedure is detailed in Table 30 and indicates that two jaw procedures predominate among the group with significant post-operative occlusal change. Two jaw procedures, including six one piece Le Fort I with sagittal split osteotomies, three two piece Le Fort I with sagittal split osteotomies and one three-piece Le Fort I with an inverted-L osteotomy, make up nearly 60%

of the surgeries in the relapse group, while they make up only about 17% of the non-relapsing surgeries.

Table 30.--Surgical Treatment of Relapse Patients vs. Non-relapse Patients

Surgery	Relapse Patients (n)	(%)	Nonrelapse Patients (n)	(%)
IVRO	0	0.00	15	13.04
BSSO	4	23.53	51	44.35
BSSO with genio	0	0.00	10	8.69
BSSO with mnd anterior osteotomy	0	0.00	1	0.87
LeFort I	1	5.88	6	5.22
LeFort I with genio	0	0.00	3	2.61
2-piece LeFort I	1	5.88	4	3.48
2-piece LeFort I with genioplasty	0	0.00	2	1.74
3-piece LeFort I	0	0.00	1	0.87
3-piece LeFort I with genioplasty	1	5.88	0	0.00
LeFort I and BSSO	3	17.65	10	8.69
LeFort I, BSSO with genioplasty	3	17.65	3	2.61
2-piece LeFort I & BSSO	0	0.00	3	2.61
2-piece LeFort I, BSSO and genioplasty	3	17.65	1	0.87
2-piece LeFort I, BSSO and suprahyoid myotmy	0	0.00	1	0.87
3-piece LeFort I & BSSO	0	0.00	1	0.87
3-piece LeFort I and inverted-L osteotomy	1	5.88	0	0.00
IVRO and LeFort I	0	0.00	1	0.87
Inverted-L osteotomy	0	0.00	1	0.87
Maxillary segmental osteotomy	0	0.00	1	0.87
Total	17	100.00	115	100.00

Stratification by rigid and non-rigid fixation methods (see Table 31) show that some type of rigid fixation was utilized in 76% of patients with significant post-operative occlusal change as opposed to 58% of the non-relapsing patients.

Table 31.--Rigid vs. Non-rigid Fixation in Relapse and Non-relapse Patients

Fixation	Relapse Patients (n)	(%)	Non-relapse Patients (n)	(%)
Rigid	13	76.47	67	58.26
Non-rigid	4	23.53	48	41.74

Stratification by surgical practice shows that approximately 65% of patients exhibiting significant post-operative occlusal change were treated at one surgical practice while 35% were treated at the second surgical practice. Approximately the same proportion of non-relapsing patients were treated at both practices. Table 32 details this data.

Table 32.--Surgical Practice Treating Relapse and Non-relapse Patients

Surgical Practice	Relapse Patients (n)	(%)	Non-relapse Patients (n)	(%)
x	6	35.30	56	48.70
y	11	64.70	59	51.30
Total	17	100.00	115	100.00

Stratification by orthodontist shows that patients who exhibited significant post-operative occlusal change were fairly evenly divided among the group of thirty two orthodontic practitioners represented. Table 33 details this distribution.

Table 33.--Orthodontic Practice Treating Relapse and Non-relapse Patients

Orthodontist	Relapse Patients (n)	(%)	Non-relapse Patients (n)	(%)
i	2	11.77	7	6.09
ii	1	5.88	10	8.70
iii	1	5.88	11	9.56
iv	1	5.88	0	0.00
v	2	11.77	21	18.26
vi	0	0.00	4	3.47
vii	0	0.00	4	3.47
viii	1	5.88	9	7.83
ix	1	5.88	5	4.34
x	2	11.77	8	6.96
xi	0	0.00	1	0.87
xii	2	11.77	9	7.83
xiii	0	0.00	1	0.87
xiv	0	0.00	3	2.61
xv	0	0.00	1	0.87
xvi	0	0.00	2	1.74
xvii	1	5.88	2	1.74
xviii	0	0.00	2	1.74
xix	0	0.00	1	0.87
xx	1	5.88	1	0.87
xxi	0	0.00	2	1.74
xxii	1	5.88	0	0.00
xxiii	0	0.00	1	0.87
xxiv	0	0.00	3	2.61
xxv	0	0.00	1	0.87
xxvi	0	0.00	1	0.87
xxvii	0	0.00	1	0.87
xxviii	0	0.00	1	0.87
xxvix	0	0.00	1	0.87
xxx	0	0.00	1	0.87
xxxi	1	5.88	0	0.00
xxxii	0	0.00	1	0.87
TOTAL:	17	100.00	115	100.00

Due to the presence of temporomandibular symptomatology in twenty five cases of the resultant sample, stratification based upon a pre-operative diagnosis of any type of temporomandibular pathology was performed for completeness of information. As can be seen from the data in Table 34, the presence of a pre-operative diagnosis of a temporomandibular problem was as common in the non-relapsing patients as in the patients exhibiting significant post-operative occlusal change.

Table 34.--Pre-operative Diagnosis of Temporomandibular Pathology in Relapse and Non-relapse Patients

Pre-operative TM diagnosis	Relapse Patients (n)	(%)	Non-relapse Patients (n)	(%)
Present	2	11.76	14	12.17
Absent	15	88.24	101	87.83
Total	17	100.00	115	100.00

DISCUSSION

Seventeen of the 132 subjects that participated in this investigation demonstrated moderate to severe occlusal change an average of 9.1 years post-operatively (range of 6.6 to 13.5 years). These patients each met at least one criterion demonstrating notable post-operative occlusal change.

Stratification

Stratification of the data by numerous potentially key variables allowed for a comparison of the group which exhibited notable post-operative occlusal change and the group of those individuals not exhibiting this degree of occlusal change.

In this study, gender was not a factor differentiating those with significant post-operative occlusal change from the non-relapsing group. It is interesting to note, however, that the two patients in the resultant sample with a history of condylar resorption were both women and both experienced some degree of relapse; one patient was retreated prior to this investigation and one patient met the criteria of this investigation for inclusion in the

group exhibiting significant post-operative occlusal change.

Age differences were seen between the two groups with 59% of the patients exhibiting significant occlusal change being under twenty years of age while only 34% of the non-relapsing patients were less than twenty years old. This relatively higher proportion of younger patients in the occlusal relapse group cannot be explained in terms of continued horizontal growth since only one mandibular prognathic patient was found within the group exhibiting significant post-operative occlusal change. This particular patient relapsed within two years and was retreated surgically for maxillary constriction with an open bite and not because of a horizontal relapse or continued growth; she is included in this investigation's group of individuals exhibiting moderate to severe occlusal change post-operatively due to the presence of an open bite and excessive overjet. Continued vertical growth or maxillary vertical instability in the younger age group may be a possible consideration. Twice as many occlusal relapse patients that had a pre-operative diagnosis of vertical maxillary excess were found in the under-twenty age bracket as opposed to the number of patients over the age of twenty years. Possible vertical instability or

continued posterior vertical growth is supported by the fact that 83% of these relapsing teens relapsed into an open bite eventhough only 33% of them had a pre-operative open bite. Nonetheless, previous reports of post-surgical relapse secondary to continued maxillary vertical growth or decreased vertical stability of teenage patients in particular are lacking in the literature for either the treatment of vertical maxillary excess alone or in bimaxillary surgical procedures.

Stratification based upon pre-operative maxillomandibular relationship showed that mandibular retrognathia with a concomitant open bite was approximately 2.5 times more common in the group with significant post-operative occlusal change as it was in the non-relapsing group. Vertical maxillary excess was also 2.5 times more common as a pre-operative diagnosis in the occlusal relapse group as compared to the non-relapse group whether or not an open bite accompanied this diagnosis. The largest proportional difference between patients exhibiting significant occlusal change and the patients without this degree of change was found with maxillary constriction where it was 4.5 times more common a pre-operative diagnosis in the occlusal relapse cases than in the more stable group. This data is quite interesting but cannot be

compared to previous findings since the literature does not speak to the significance of pre-operative maxillomandibular relationships in subsequent post-operative relapse except with regard to Angle classification. Suffice it to say that the most unexpected finding with regard to this stratification is that maxillary constriction would appear to play a more significant role in post-operative relapse than it has been given credit for in the literature. It is likely that this has been due to an inadvertent sin of omission since the large majority of relapse studies are skeletal studies in which the data has been obtained from serial lateral cephalometric radiographs, a method from which transverse measurements cannot be made.

It is not surprising to note that mandibular retrognathia was a pre-operative diagnosis in fourteen of the seventeen patients (82.36%) with significant occlusal change found in this investigation. In fact, proportionally, this percentage is not that much higher than the 64% of the non-relapsing sample which had a pre-operative maxillomandibular relationship of mandibular retrognathia.

When evaluating the results of stratification based upon surgeries performed, the key observation was that

nearly 58% of the patients exhibiting moderate to severe occlusal change had undergone bimaxillary surgery which included a single or multiple-piece Le Fort I with either a sagittal split osteotomy or an inverted-L osteotomy. Only 16.52% of the non-relapsing patients had undergone similar procedures. Generally, the literature does not report any difference in relapse frequency or amount between single jaw and two jaw procedures in the literature. Two exceptions are noted. LaBanc, Turvey and Epker, after evaluating one hundred consecutive patients following two jaw surgery, wrote that "it appears that there is an increased incidence of relapse when compared to single-jaw surgery." (81) This statement, however, was not supported by any data, descriptive or otherwise, as to how many patients relapsed to what degree or over what period of evaluation. Four years later, Doyle, in a serial radiographic evaluation of fifty consecutively treated patients from a private practice which included fourteen cases of simultaneous mobilization of the entire maxilla and mandible, found a four-fold increase in relapse from that seen in the cases treated with a sagittal split osteotomy alone (33).

Stratification based upon rigid vs. non-rigid fixation showed a somewhat higher percentage of patients with

significant post-operative occlusal change that were fixated rigidly than were non-relapsing patients. The exact type of rigid fixation used on each patient has not been described but included screw fixation of two or more screws per osteotomy side or plate and screw fixation. The literature generally indicates greater stability with rigid fixation than non-rigid fixation (33, 61, 72, 85, 87, 89, 99, 118, 125, 134, 148, 153). A more detailed analysis of fixation type within the resultant sample may be able to shed some light on these findings as might an analysis of the magnitude of surgical movements since there is some suggestion from the literature that larger surgical movements may relapse more even when rigid fixation is utilized (84, 151). Neither analysis was possible within the methodologic parameters of this investigation.

In 1990, Arnett and Tamborello suggested that one mechanism of late post-surgical relapse could be associated with temporomandibular joint loading via numerous mechanisms, including effects of the fixation hardware (2). Most reports of late relapse secondary to significant condylar change have not described the types of fixation utilized (2, 29, 64, 69, 71, 88, 127, 132). Within the last five years, however, more attention has been given to the phenomenon of significant condylar morphologic change,

its relationship to long-term orthognathic surgical relapse and possible attendant variables. In 1991, Moore and his colleagues (95) reported on a series of five of four hundred twenty one post-orthognathic surgery patients who experienced postoperative condylar resorption over the long term; all five cases had been fixated with Champy miniplates.

In 1994, Scheerlinck and his colleagues evaluated one hundred twenty four sagittal split osteotomy cases that had been fixated with Champy miniplates and found eight of one hundred twenty four patients (6.45%) had evidence of significant condylar resorption concurrent with significant relapse over the long term.

In 1994, De Clerq and his colleagues (31) reported on twenty nine high angle mandibular deficiency patients treated with bimaxillary surgery fixated with monocortical plates and screws after forcible posteriorization of the proximal surgical segment. Condylar change was cephalometrically measured from articulare to the edge of the miniplate and any change greater than two millimeters over twenty four months was considered condylar resorption, a finding seen in 31% of their sample.

Prevalence of condylar resorption in non-rigidly fixated cases was described that same year by Merkx and Van

Damme (94). Eight of three hundred twenty nine (2.43%) sagittal split osteotomy patients, all fixated with superior border wires and six weeks of intermaxillary fixation, were found to exhibit cephalometric evidence of condylar resorption.

Probably the most interesting study for consideration of the role of fixation method in long-term relapse was also done in 1994 by Bouwman and his colleagues (19). The condyles of one thousand twenty five consecutively treated orthognathic surgery patients treated at one hospital in Amsterdam were radiographically evaluated. Those cases treated before August, 1988 had been fixated with superior border wires and four to six weeks of intermaxillary fixation while those treated after this date were fixated with three superior border screws per side and no post-surgical intermaxillary fixation. After one year, condylar change indicative of condylar resorption was seen in 26.4% of the Class II patients fixated with wires and intermaxillary fixation while condylar resorption was seen in 11.9% of the Class II patients fixated rigidly.

Discussion of the clinical implications of these radiographic condylar changes is noticeably lacking in most of the previous reports. The results of these retrospective investigations leave the question of the role

of fixation method in long-term post-surgical relapse subject to further study.

Stratification of the occlusal relapse and non-relapse patients by surgical and orthodontic practice found no clear trend. This has been noted generally throughout the literature with the only exception being a clinical opinion espoused in the discussion of a retrospective, multi-practitioner study (129).

Given the methodologic parameters of this investigation, there is no absolute way to know that all of these cases of moderate to severe post-operative occlusal change occurred over the long term as opposed to more short term change that may have simply persisted through the long term. It can be stated, however, that the follow-up notes from the oral surgical chart of each patient exhibiting significant occlusal change failed to make mention of either skeletal or occlusal relapse. Nonetheless, it can also be said that these are cases in which moderate to severe occlusal change presumably occurred subsequent to normal surgical follow-up and persisted for 6.6 to 13.5 years post-operatively. Suffice it to say that it is impossible to determined which, if any, of these cases may be due to post-operative condylar change significant enough to cause the degree of occlusal change observed in the course of this investigation.

Future Studies

The results of this investigation leave many questions unanswered and pave the way for potential follow-up investigations.

Methodologically, further comparison of the results of the self-administered wax bite and bite stick registrations to professionally administered wax bites and overjet determinations is warranted. The pilot study findings of this investigation demonstrated that a self-administered Aluwax bite sent through the federal mail system was accurate to within 0.4 mm of professionally made occlusal models (with a range of 0.2 mm to 0.8 mm depending on the landmarks measured). Overjet measurements taken from these same Aluwax bites averaged a 0.15 mm difference from those taken from the professionally obtained models; bite stick differences averaged 0.575 mm of difference from the models. These findings indicate that, indeed, this method of occlusal registration is accurate enough to use for occlusal studies if the patient provides an accurate centric occlusion bite. Comparison of twenty five to thirty percent of the self-administered bites obtained in this investigation to professionally made wax bites would lend greater credence to the validity of this method of occlusal relationship determination.

The cases exhibiting significant post-operative occlusal change found in this investigation simply demonstrated occlusal relapse. The assumption is made that this occlusal relapse has both a skeletal component as well as a dental component in most cases. Evaluation of serial cephalometric radiographs, including a contemporary radiograph, as well as evaluation of serial models could help determine if this is, in fact, the case.

Finally, each of the patients exhibiting moderate to severe post-operative occlusal change could be matched against patients from the non-relapse group and then be evaluated for morphologic condylar change subsequent to their orthognathic surgery. Such a study could provide important information as to the clinical significance of condylar change following orthognathic surgery.

SUMMARY AND CONCLUSIONS

This descriptive, cross-sectional investigation sought to estimate the prevalence of clinically significant, long term, post-surgical occlusal change following combined orthodontic and orthognathic surgical treatment of patients treated from January 1, 1980 thru December 31, 1989 in two oral and maxillofacial surgical practices in northeast Ohio.

A pilot study was initially performed to determine the accuracy and reliability of a self-administered wax bite registration and bite stick overjet marking system sent through the federal mail. This system was subsequently utilized to obtain the bite registrations of one hundred thirty two patients which then constituted the resultant sample of this investigation.

The bite registrations were subsequently analyzed by the principal investigator and each was assessed according to five occlusal criteria, the presence of any one of which constituted clinically significant post-surgical occlusal change.

Based upon the criteria set forth in this investigation, the prevalence of moderate to severe long-

term occlusal change was estimated at 12.9%. The average follow-up period of the cases evaluated was 9.1 years with a range of 6.6 to 13.5 years. Stratification of the results by gender, age at the time of surgery, pre-operative maxillomandibular relationship, surgical procedure, fixation technique, surgical practice, orthodontic practice and the presence of pre-operative temporomandibular joint signs or symptoms was undertaken for further descriptive purposes.

Based upon the results of this investigation, the following conclusions can be drawn:

1) An Aluwax bite registration supplemented with a bite stick overjet marking system, both self-administered, appear to reliably reproduce centric relation occlusion and are durable enough to be sent through the federal mail system if packaged properly.

2) The prevalence of clinically significant post-surgical occlusal change based upon the presence of an anterior open bite, anterior crossbite, posterior crossbite or an overjet of five millimeters or greater is estimated to be 12.9% within the patient population studied.

3) Stratification of the data showed that five variables were more common to the group exhibiting significant long-term post-operative occlusal change than the group of patients not exhibiting the same degree of occlusal change:

- age under 20 years,

- surgical practice,

- pre-operative maxillomandibular relationships of mandibular retrognathia with a concomitant open bite, vertical maxillary excess and maxillary constriction,

- bimaxillary surgery which includes a Le Fort I osteotomy with a mandibular advancement osteotomy, or

- rigid fixation.

APPENDIX 1

Pilot Study Measurements

Pt: A

Model:	Upper 3 - 3: 33.9		
Wax #1:	33.4		
	34.1		
	33.8	Mean: 33.8	Difference: 0.1
Wax#2:	35.2		
	35.2		
	33.5	Mean: 34.6	Difference: 0.7
Aluwax:	34.6		
	34.6		
	34.1		
	34.2		
	34.2	Mean: 34.3	Difference: 0.4

Model:	Upper 6-6, MB cusp: 48.4		
Wax #1:	48.4		
	48.2		
	47.2	Mean: 47.9	Difference: 0.5
Wax #2:	49.4		
	45.1		
	48.2	Mean: 47.6	Difference: 0.8
Aluwax:	49.3		
	48.4		
	48.6		
	49.3		
	49.7	Mean: 48.5	Difference: 0.1

Pt: A (continued)

Model:	Upper 6-6, Central Groove: 43.8		
Wax #1:	42.6		
	42.9		
	43.2	Mean: 42.9	Difference: 0.9
Wax #2:	45.6		
	45.5		
	44.3	Mean: 45.1	Difference: 1.3
Aluwax:	45.2		
	44.7		
	44.5		
	45.4		
	45.7	Mean: 45.1	Difference: 1.0

Model:	Upper 6-6, ML cusp: 37.4		
Wax #1:	37.3		
	37.5		
	36.1	Mean: 37.0	Difference: 0.4
Wax #2:	39.1		
	39.7		
	38.2	Mean: 39.0	Difference: 1.6
Aluwax:	37.8		
	36.9		
	37.8		
	38.6		
	39.1	Mean: 38.0	Difference: 0.6

Model:	Lower 6-6, MB cusp: 41.4		
Wax #1:	41.7		
	41.5		
	40.9	Mean: 41.4	Difference: 0.0
Wax #2:	42.5		
	44.6		
	44.9	Mean: 44.0	Difference: 2.6
Aluwax:	41.1		
	42.7		
	41.5		
	42.5		
	42.3	Mean: 42.2	Difference: 0.8

Pt: A (continued)

Model:	Lower 6-6: Central Groove: 40.4		
Wax #1:	38.5		
	38.5		
	38.3	Mean: 38.4	Difference: 2.0
Wax #2:	41.0		
	41.5		
	40.1	Mean: 40.9	Difference: 0.5
Aluwax:	40.3		
	39.9		
	39.9		
	40.6		
	40.5	Mean: 40.2	Difference: 0.2

Model:	open bite?	no
Wax #1:	open bite?	Left side and anterior
		Right and left side
		Left side and anterior
Wax #2:	open bite?	no
		no
		no
Aluwax:	open bite?	no
		no
		no
		no
		no

Model: cross-bite? no
No cross-bite was seen on any wax sample

Model: overjet: 2.1 mm

Stick #1:	3.0	Aluwax #1:	2.0
#2:	3.4	#2:	1.9
#3:	3.4	#3:	2.0
#4:	3.0	#4:	1.8
#5:	3.0	#5:	2.2
#6:	3.3		
#7:	3.2		
#8:	3.1		
#9:	2.3		
#10:	3.0		
Mean:	3.1	Mean:	2.0
Difference:	1.0	Difference:	0.1

Pt: B

Model: Upper 3-3: 35.7
Wax #1: 35.2
35.3
33.5 Mean: 34.7 Difference: 1.0
Wax #2: 36.4
37.8
36.0 Mean: 36.7 Difference: 1.0
Aluwax: 35.0
34.8
35.1 Mean: 35.0 Difference: 0.7

Model: Upper 6-6, MB cusp: 48.5
Wax #1: 44.8
44.6
40.0 Mean: 43.1 Difference: 5.4
Wax #2: 47.6
47.0
47.4 Mean: 47.3 Difference: 1.2
Aluwax: 49.7
47.6
49.0 Mean: 48.8 Difference: 0.3

Model: Upper 6-6, Central groove: 44.1
Wax #1: 41.0
40.2
35.6 Mean: 38.9 Difference: 5.2
Wax #2: 43.2
43.7
43.1 Mean: 43.3 Difference: 0.8
Aluwax: 44.9
44.3
45.7 Mean: 45.0 Difference: 0.9

Model: Upper 6-6, ML cusp: 37.2
Wax #1: 34.2
34.2
28.2 Mean: 32.2 Difference: 5.0
Wax #2: 36.0
37.5
36.0 Mean: 36.5 Difference: 0.7
Aluwax: 36.8
36.5
38.2 Mean: 37.2 Difference: 0.0

Pt: B (continued)

Model: Lower 6-6, MB cusp: 43.0
Wax #1: 41.3
41.5
37.2 Mean: 40.0 Difference: 3.0
Wax #2: 43.1
43.3
42.7 Mean: 43.0 Difference: 0
Aluwax: 43.4
45.4
43.1 Mean: 44.0 Difference: 1.0

Model: Lower 6-6, Central groove: 38.3
Wax #1: 40.0
38.6
33.7 Mean: 37.4 Difference: 0.9
Wax #2: 38.8
38.7
38.9 Mean: 38.8 Difference: 0.5
Aluwax: 38.4
40.2
38.8 Mean: 39.1 Difference: 0.8

Model: Open bite? no
No open bite was seen on any wax sample

Model: Cross-bite? no
No cross-bite was seen on any sample

Model overjet: 0.5 mm

Stick		Aluwax	
#1:	1.1	#1:	0.8
#2:	1.5	#2:	0.6
#3:	1.1	#3:	0.6
#4:	1.7		
#5:	0.9		
#6:	1.1		
#7:	1.2		
#8:	0.6		
#9:	0.7		
Mean:	1.1	Mean:	0.7
Difference:	0.6	Difference:	0.2

Pt: C

Model: Upper 3-3: 32.1
Wax #1: 30.1
30.8
31.4 Mean: 30.8 Difference: 1.3
Wax #2: 33.2
34.9
33.6 Mean: 33.9 Difference: 1.8
Aluwax: 33.4
33.2
33.9 Mean: 33.5 Difference: 1.4

Model: Upper 6-6, MB cusp: 47.9
Wax #1: 46.8
46.4
47.1 Mean: 46.8 Difference: 1.1
Wax #2: 47.2
44.4
46.8 Mean: 46.1 Difference: 1.8
Aluwax: 48.0
47.0
48.8 Mean: 47.9 Difference: 0

Model: Upper 6-6, Central groove: 43.9
Wax #1: 42.8
43.2
44.1 Mean: 43.4 Difference: 0.5
Wax #2: 45.1
42.9
44.4 Mean: 44.1 Difference: 0.2
Aluwax: 44.4
43.8
44.2 Mean: 44.1 Difference: 0.2

Model: Upper 6-6, ML cusp: 36.9
Wax #1: 35.8
36.0
36.5 Mean: 36.1 Difference: 0.8
Wax #2: 36.2
33.4
38.8 Mean: 36.1 Difference: 0.8
Aluwax: 36.8
35.9
36.7 Mean: 36.5 Difference: 0.4

Pt: C (continued)

Model: Lower 6-6, MB cusp: 41.1

Wax #1:	41.9		
	42.1		
	41.1	Mean: 41.7	Difference: 0.6
Wax #2:	42.1		
	41.1		
	42.0	Mean: 41.7	Difference: 0.6
Aluwax:	41.3		
	40.8		
	41.8	Mean: 41.3	Difference: 0.2

Model: Lower 6-6, Central groove: 37.6

Wax #1:	37.8		
	38.2		
	37.3	Mean: 37.8	Difference: 0.2
Wax #2:	38.0		
	37.7		
	40.0	Mean: 38.6	Difference: 1.0
Aluwax:	37.4		
	36.7		
	37.6	Mean: 37.2	Difference: 0.4

Model: Open bite? No

Wax #1: NA

Wax #2: No open bites on any sample

Aluwax: No open bites on any sample

Model: Cross-bite? No

No cross-bite was seen on any sample

Model: Overjet: 3.2 mm

Stick	#1: 3.4	Aluwax	#1: 3.3
	#2: 5.2		#2: 3.0
	#3: 3.2		#3: 3.1
	#4: 5.2		
	#5: 3.8		
	#6: 5.7		
	#7: 1.3		
	#8: 3.1		
	#9: 3.2		
	#10: 3.4		
	Mean: 3.8		Mean: 3.1
	Difference: 0.6		Difference: 0.1

Pt: D

Model: Upper 3-3: 35.3

Wax #1:	35.1		
	34.4		
	35.6	Mean: 35.0	Difference: 0.3
Wax #2:	35.5		
	34.9		
	35.2	Mean: 35.2	Difference: 0.1
Aluwax:	34.9		
	35.5		
	35.4	Mean: 35.3	Difference: 0.2

Model: Upper 6-6, MB cusp: 51.1

Wax #1:	51.5		
	51.5		
	51.4	Mean: 51.5	Difference: 0.4
Wax #2:	49.4		
	50.7		
	51.8	Mean: 50.6	Difference: 0.5
Aluwax:	51.2		
	51.6		
	51.1	Mean: 51.3	Difference: 0.2

Model: Upper 6-6, Central groove: 45.6

Wax #1:	45.7		
	46.0		
	45.9	Mean: 45.9	Difference: 0.3
Wax #2:	47.6		
	45.3		
	46.5	Mean: 46.5	Difference: 0.9
Aluwax:	46.6		
	46.6		
	46.1	Mean: 46.4	Difference: 0.8

Model: Upper 6-6, ML cusp: 37.5

Wax #1:	37.4		
	36.2		
	36.9	Mean: 36.8	Difference: 0.7
Wax #2:	37.0		
	36.2		
	37.7	Mean: 37.0	Difference: 0.5
Aluwax:	38.1		
	38.6		
	38.3	Mean: 38.3	Difference: 0.8

Pt: D (continued)

Model: Lower 6-6, MB cusp: 45.2
Wax #1: 45.7
45.9
44.9 Mean: 45.5 Difference: 0.3
Wax #2: 45.0
46.4
45.4 Mean: 45.6 Difference: 0.4
Aluwax: 45.3
45.2
45.5 Mean: 45.3 Difference: 0.1

Model: Lower 6-6, Central groove: 41.8
Wax #1: 41.4
41.3
41.8 Mean: 41.5 Difference: 0.3
Wax #2: 41.1
41.2
41.6 Mean: 41.3 Difference: 0.5
Aluwax: 42.6
42.6
42.1 Mean: 42.4 Difference: 0.6

Model: Open bite? No
No open bite on any wax samples

Model: Cross-bite? No
No cross-bite was seen on any wax samples

Model: Overjet: 2.1

Stick		Aluwax	
#1:	2.1	#1:	1.9
#2:	1.9	#2:	2.0
#3:	3.4	#3:	1.9
#4:	2.2		
#5:	1.7		
#6:	1.9		
#7:	1.7		
#8:	2.0		
#9:	1.2		
Mean:	2.0	Mean:	1.9
Difference:	0.1	Difference:	0.2

APPENDIX 2

List of materials sent to each study participant

2 Aluwax bites
2 wooden bite sticks
1 retainer case
1 pencil
1 pre-addressed, stamped padded return mailer
1 consent form
1 copy of "Directions for marking your bite if you have an underbite"
1 copy of "Directions for marking your bite if you have an overbite"
1 copy of "Directions for taking your wax bite"
1 questionnaire

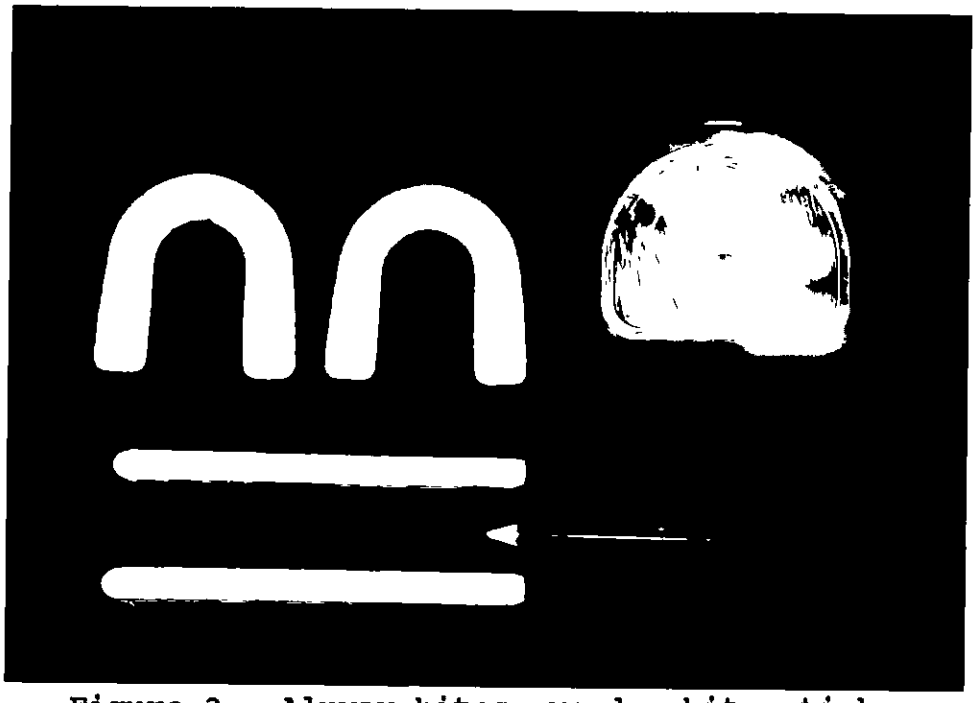


Figure 3. Aluwax bites, wooden bite sticks, pencil and retainer case sent to each study participant

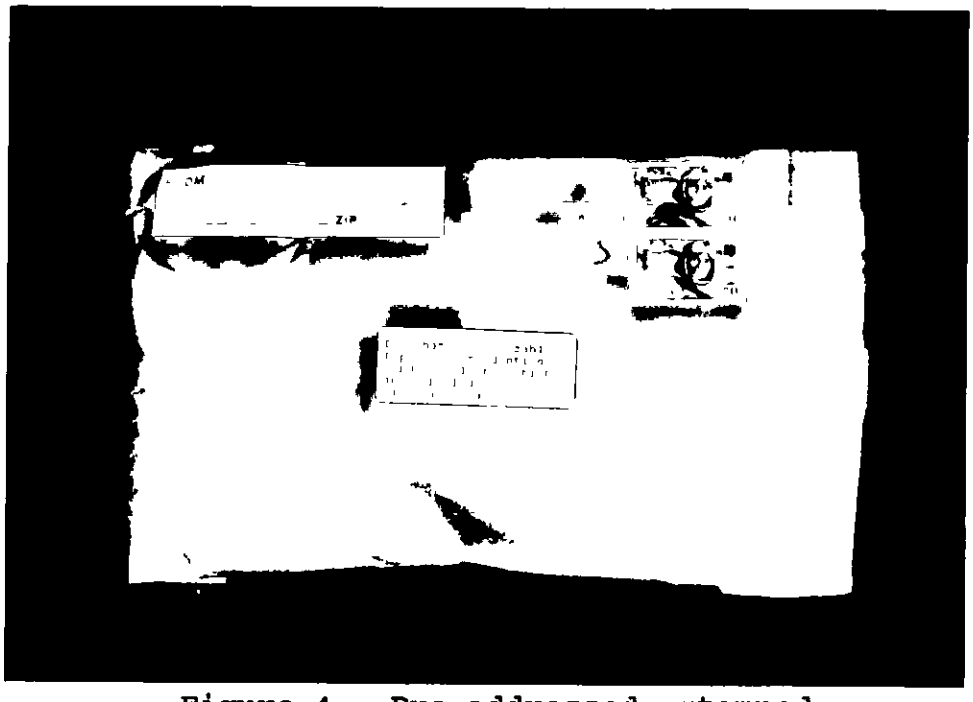


Figure 4. Pre-addressed, stamped padded return mailer sent to each study participant

Human Investigation Consent Form
Consent to Participate in Research Study

I have been asked to participate in a research study entitiled: A Long-Term Evaluation of Occlusal Stability Following Orthognathic Surgery

by:	Sharon R. Schmahl, D.D.S.	Principal investigator
	Jerold Goldberg, D.D.S.	Co-investigator
	Mark G. Hans, D.D.S., M.S.D.	Co-investigator
	Suchitra Nelson, M.S., Ph.D.	Co-investigator

I understand that this study involves:

A) Completing a written questionnaire
B) Making a wax bite registration
C) Marking a bite stick

I further understand that:

1. The wax bite will be made using warm water. The recommended temperature of the water is the same as when washing dishes by hand or taking a bath. If the water that is used is too hot, I risk being scalded or burned.

2. I will not be required to pay any cost for the materials to be used in the study.

3. The information from the study is confidential and will be contained in a data base for future study.

4. Dr. Goldberg in the Department of Oral and Maxillofacial Surgery and Dr. Schmahl, Dr. Hans and Dr. Nelson in Orthodontics will be coordinating this study and will be available to answer any questions about the study. The telephone number in Oral and Maxillofacial Surgery is (216)368-2538 and the telephone numbers in Orthodontics are (216)368-3469 and (216)368-4649.

5. I have the right to refuse to participate in this study. In this case, my refusal will not affect the medical or dental care I can receive in the School of Dentistry at Case Western Reserve University or University Hospitals.

I have read the above information and understand the risks and benefits involved in participation in this study.

_____ _____

Date Subject/Patient

Figure 5. Consent form sent to each study participant

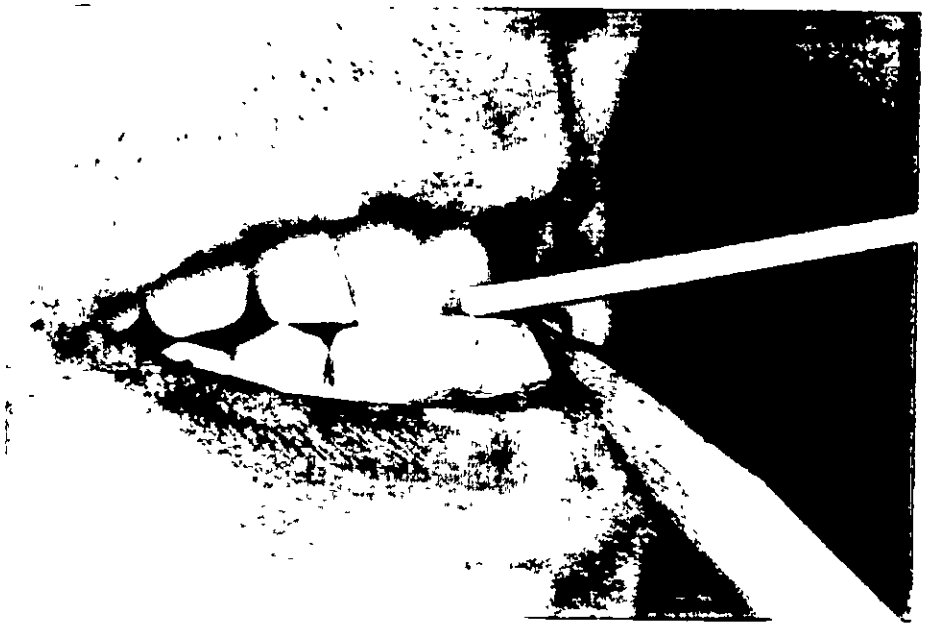
DIRECTIONS FOR MARKING YOUR BITE STICK IF YOU HAVE AN UNDERBITE

If you have an UNDERBITE (your upper front teeth are behind your lower front teeth when you bite together):

1. Bite your teeth together. Place the flat side of the enclosed wooden stick against the front of the most forward upper front tooth. Slide the stick down the tooth until it touches the top edge of the lower tooth.

2. Take the enclosed pencil and mark a line on the underside of the stick RIGHT UP AGAINST THE LOWER TOOTH.

3. Take the stick out of your mouth. Find the side of the stick with the pencil mark on it and draw a "2" on this side of the stick.



THANKS FOR YOUR EFFORT!!!

Figure 6. Directions for marking the bite sticks for patients with underbites which was sent to each study participant

DIRECTIONS FOR MARKING YOUR BITE STICK IF YOU HAVE AN OVERBITE

If you have an overbite (your upper front teeth overlap your lower front teeth when you bite together):

1. Bite your teeth together. Place the flat side of the enclosed wooden stick against the front of the most foward lower front tooth. Slide the stick up the tooth until it touches the bottom edge of the upper tooth.

2. Take the enclosed pencil and mark a line on the top of the stick RIGHT UP AGAINST THE UPPER TOOTH.

3. Take the stick out of your mouth. Find the side of the stick with the pencil mark on it and draw a "1" on this side of the stick.



THANK YOU FOR YOUR EFFORT!!!

Figure 7. Directions for marking the bites sticks for patients with overbites which was sent to each study participant

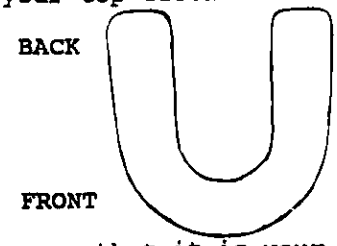
DIRECTIONS FOR TAKING YOUR WAX BITE

For this study, it is important to get a marking of your NORMAL BITE.
Practice biting your teeth together a few times
before putting the wax in your mouth.
BE SURE THAT YOU ARE BITING WITH YOUR BACK TEETH HITTING TOGETHER.
(If your back teeth don't normally come together, practice the bite you have when chewing food or gum.)

1. Place one of the pieces of wax bite material in a cup or bowl of warm water. The temperature at which you wash dishes or take a bath will work great. **DO NOT MAKE THE WATER TOO HOT TO TOUCH!!!** Make sure that the water covers the wax completely. Leave the wax in the water for 2 to 3 minutes.

2. Remove the wax from the water and place the wax in your mouth against the biting surfaces of your top teeth.

   The ends of the wax go to the back of your mouth.



3. Now bite down into the wax. Make sure that it is your normal bite - the one that you practiced with your back teeth together. **BITE ALL THE WAY THROUGH THE WAX UNTIL YOUR TEETH TOUCH.** Don't try to talk with the wax in your mouth. Keep the wax in your mouth for approximately 30 seconds.

4. Open your mouth and gently remove the wax from your mouth. The wax will probably be stuck to your upper or lower teeth. Use your thumb or forefinger to gently pry the wax loose being careful not to distort the wax.

5. Immediately place the wax in a cup or bowl of COLD water. Leave it in the water for about 30 seconds. Take it out of the water and let it air dry. After it is dry you may place it in the retainer case to return to Case Western Reserve University. Keep the envelope out of the sun and away from very warm locations.

6. Repeat this process again with the second piece of wax bite material. When you are done place this wax bite in the same retainer case as before. Place the retainer case (along with the bite stick, questionnaire and consent form) in the enclosed self-addressed, stamped mailer and put it in the mail.

THANK YOU VERY MUCH FOR YOUR EFFORTS!!!

Figure 8. Directions for taking the wax bite sent to each study participant

QUESTIONNAIRE

1. Is the way you bite your teeth together now better or worse than your bite before your jaw surgery? (Please put an "X" on the line below to show how much change has occured.)

Much worse — No change — Much better

2. How has your facial appearance changed as compared to how you looked before your jaw surgery? (Please put an "X" on the line below to show how much change you feel has occured.)

Much worse — No change — Much better

3. We assume that your bite was put into a new position at the time of your jaw surgery. Most likely your teeth were wired together or you had rubber bands holding your teeth together in the new bite for a few weeks after the surgery. Has your bite changed or shifted at any time since the wires or rubber bands were removed up to the present time?

_____ Yes

_____ No

4. If you answered "yes" to question #3, when did you first notice that your bite was changing?

_____ Within the first 1 to 2 weeks after your jaws were no longer wired shut.

_____ Within the first year after surgery.

_____ 1 or more years after the jaw surgery was completed.

_____ I have not noticed any change in my bite since the jaw surgery.

5. Are you satisfied with the results of your jaw surgery?

_____ Yes

_____ No

Figure 9. Page 1 of the Questionnaire sent to each study participant

6. Knowing all that you know now about your jaw surgery, including how it was going to turn out, would you still have chosen to have the jaw surgery?

_____ Yes

_____ No

_____ I'm not sure

7. What was the name of your orthodontist or the name of the orthodontist or orthodontic clinic where you were treated?

_____

8. What month and year did you get your braces on?

_____

9. What month and year did you get your braces off?

_____

10. Have you had braces put back on at any time after the date that you gave in answering question #9?

Yes _____

No _____

11. If you answered yes to question #10, when did you have the braces put back on?

_____

Comments:

THANK YOU VERY MUCH FOR YOUR TIME AND EFFORT!!!

Figure 10. Page 2 of the Questionnaire sent to each study participant

APPENDIX 3

Wax Bite and Bite Stick Measurements

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
1	1.12	+	-	R: Cl I L: Cl I	mnd prog	IVRO/9	9.4
2	1.36	+	-	R: Cl I L: Cl I	max constr	2 piece LFI	11.0
3	2.8	+	-	R: Cl I L: Cl I	VME, apertogn, mnd retro	LF I, BSSO/ rigid 9	8.1
4	4.48	+	-	R: Cl I L: Cl I	mnd retro	BSSO/	10.0
5	0	0	-	R: Cl I L: Cl III	mnd prog	IVRO/ rigid 10	8.3
6	2.52	+	-	R: Cl I L: Cl I	mnd retro	BSSO, genio/ rigid 29	10.11
7	1.5	+	-	R: Cl I L: Cl I	max hyper, mnd retro	2 piece LF I, BSSO, genio/ rigid 9	9.6
8	0	0	-	R: Cl I L: Cl III	mnd prog, max hypo	IVRO, infraorb HA implants/ rigid 24	8.5

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
9	1.75	+	-	R: Cl I L: Cl I	mnd prog	IVRO/ rigid 17	9.11
10	3.8	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid	7.10
11	3.6	+	-	R: Cl I L: Cl III	mnd retro	BSSO/ rigid	8.5
12	0	0	-	R: Cl I L: Cl I	max hypo	3 piece LF I/ rigid	8.6
13	1.52	+	-	R: Cl I L: Cl I	mx hyper, mx constr, mnd retro	2 piece LF I, BSSO/ rigid	6.6
14	2.35	+	-	R: Cl I L: Cl III	mnd retro	BSSO/ rigid 9	10.9
15	3.6	op	-	R: Cl I L: Cl I	max hyper	LF I/ rigid	7.1
16	3.45	+	-	R: Cl III L: Cl III	mnd retro	BSSO, genio, bilat arthropl & meniscus repairs/ rigid 16	9.9
17	4.16	+	-	R: Cl I L: Cl I	VME, mnd retro	LF I, BSSO, genio/ rigid	8.5
18	1.35	+	-	R: Cl I L: Cl I	mnd prog	IVRO/14	12.5
19	2.2	+	-	R: Cl I L: Cl I	mnd prog	IVRO/	13.1

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
20	2.5	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 13	10.10
21	1.8	+	-	R: Cl I L: Cl I	mnd prog, max hypo	IVRO, max proplst/ 21	9.9
22	1.95	+	-	R: Cl I L: Cl I	mnd prog	BSSO/	8.7
23	1.95	+	-	R: Cl I L: Cl III tend	mnd prog, bilat TM derangemnt	IVRO/	12.8
24	1.08	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 18	9.11
25	2.73	+	-	R: Cl I L: Cl I	mnd retro	BSSO, genio/ rigid 10	8.7
26	0	0	-	R: Cl I L: Cl III tend	mx retro	LF I/	11.11
27	3.39	+	-	R: Cl I L: Cl I	mx hyper, mnd retro	LF I, BSSO, genio/ rigid	9.7
28	1.5	+	-	R: Cl III L: Cl I	mnd retro	BSSO/ 38	10.10
29	4.1	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 9	9.10
30	1.63	+	-	R: Cl I L: Cl III tend	mnd prog	BSSO/28	9.1
31	3.93	+	-	R: Cl I L: Cl I	mnd retro	BSSO/28	11.1

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
32	1.45	+	-	R: Cl I L: Cl I	mnd prog	BSSO/ rigid	7.7
33	0.35	+	-	R: Cl I L: Cl I	mx hypo, bimalar hypopl	LF I, genio, infraorb proplast implants/ rigid	8.5
34	2.04	+	-	R: Cl I L: Cl III tend	mnd prog, focal mx hypo	IVRO, lat nasal proplast implant/ 16 then 17-51 days out/ 19 then 5-41 days out	9.5 then 9.3
35	2.56	+	-	R: Cl I L: Cl I	mnd prog	BSSO/2	6.4 then 2 days later
36	2.58	+	-	R: Cl I L: Cl I	mnd assym secondary prev mnd fx	BSSO, genio/ rigid 10	7.5
37	2.04	+	-	R: Cl I L: Cl I	mnd retro	BSSO/	11.7
38	2.91	+	-	R: Cl I L: Cl II	mnd retro, bilat TM dysfunct	BSSO/42	10.7
39	1.69	+	-	R: Cl I L: Cl II tend	mnd retro	BSSO/ rigid	9.5
40	1.5	+	-	R: Cl I L: Cl I	mnd retro	BSSO/	10.5

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
41	2.32	+	-	R: Cl I L: Cl I	VME, apertogn, mnd retro, TM dysfnct	LF I, genio/	11.5
42	2.24	+ to 0	-	R: Cl III tend L: Cl I	mx prog	mx ant set-back ext U4s	6.1
43	2.28	+	-	R: Cl I L: Cl II	mnd retro	BSSO/ rigid 9	8.2
44	0.85	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 10	9.7
45	2.12	+	+ R5&6	R: Cl I L: Cl II	mx trans hypo, mnd retro	2-piece LF I, BSSO, genio/ rigid	6.6
46	4.15	+	-	R: Cl II tend L: Cl I	mnd retro, apertogn, TM dysfnct	BSSO, ant vert ostotmy/ 33	8.8
47	3.93	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 8	8.7
48	2.82	+	-	R: Cl I L: Cl I	mnd retro	BSSO/7	8.9
49	3.3	+	-	R: Cl I L: Cl I	apertogn, mnd retro	LF I, BSSO, genio/ rigid 9	8.1
50	0.18	0	-	R: Cl III tend L: Cl III	mnd retro	BSSO/ rigid	6.9

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
51	2.51	+	-	R: Cl I L: Cl I	mnd retro, laterogn, apertogn, TM dysfnct	BSSO, genio with bone graft/ rigid 21	10.2
52	1.43	+	-	R: Cl I L: Cl I	mnd prog L lat asymmetry	IVRO/24	11.7
53	5.05	+	-	R: Cl II tend L: Cl I	md retro	BSSO/24	12.6
54	7.72	op	-	R: Cl II L: Cl II	mx hyper, md retro, sept dev	LF I, BSSO, septo/ rigid	6.8
55	1.25	+	-	R: Cl II tend L: Cl I	md retro	BSSO/ rigid	7.1
56	3.53	+	-	R: Cl I L: Cl I	md retro	BSSO/ rigid	7.3
57	3.4	op	-	R: Cl I L: Cl I	md retro, TM dysfunc with closed lock	LF I, BSSO, genio, bilat arthropl, menisc repairs, dermal grafts	10.4

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
58	2.89	+	-	R: Cl II tend L: Cl II tend	mnd retro, mnd R laterogn, mx L laterogn, mx L vert hyperpl, bilat dislocated discs	2 piece LF I, bilat arthrscp with tndn release	7.2
59	1.61	+	-	R: Cl I L: Cl III tend	mx constr, mnd retro	2 piece LF I, BSSO/ rigid	6.1
60	2.75	+	-	R: Cl II L: Cl III tend	mnd retro	BSSO/	9.2
61	1.73	+	-	R: Cl I L: Cl II tend	mx alv hyperpl	LF I/ 14	12.5
62	3.4	+	-	R: Cl II tend L: Cl I	mnd retro	BSSO/ rigid	7.0
63	3.2	+	-	R: Cl II tend L: Cl II tend	mx hyperpl, md hypopl septal dev	2 piece LF I, genio, septopl	6.10
64	2.6	+	-	R: Cl I L: Cl I	mx hyperpl, md retro	LF I, BSSO/	9.1

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
65	3.41	+	-	R: Cl II L: Cl II	VME, mnd retro, SP mnd advncment, surg-asst RPE, bilat arthrplsty & dermal grafts	LF I, BSSO/ rigid 11 then 14 days later until resurg 57 days pst-op/ rigid 58	10.3 then 10.1
66	3.3	+	-	R: Cl I L: Cl II tend	VME	LF I	11.7
67	2.72	+	-	R: Cl III tend L: Cl III tend	mnd retro	BSSO/	10.4
68	2.8	+	-	R: Cl I L: Cl I	mnd retro	BSSO, genio/ rigid 10	9.10
69	2.58	op	-	R: Cl I L: Cl I	mx constr	2 piece LF I	10.6
70	3.55	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid	8.5
71	3.15	+	-	R: Cl II tend L: Cl I	mx hypopl, mx constr, mnd retro, apertogn	3 piece LF I, BSSO/ rigid 17 then again 27 days post-op	9.10

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
72	4.68	+	-	R: Cl I L: Cl I	mnd retro, mx constr	2 piece LF I/ rigid 14	10.0
73	1.53	+	-	R: Cl III tend L: Cl III tend	mnd prog, U2s missing	IVRO, genio/	12.6
74	5.5	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 16	10.0
75	2.45	+	-	R: Cl I L: Cl I	mx hyper, mnd prog, apertogn	LF I, BSSO/ rigid 16	9.10
76	3.55	+	-	R: Cl I L: Cl I	mnd retro, mx hyperpl	LF I, turb outfxs, genio/ rigid	6.9
77	4.61	+	-	R: Cl I L: Cl II tend	mx const, mnd retro	2 piece LF I, BSSO, sprhyoid myotomy/ rigid 24	8.6
78	2.55	+	-	R: Cl I L: Cl I	mx hyprpl, VME	LF I, lat trbnctms, sptplsty/ rigid	7.7
79	3.55	+	-	R: Cl II L: Cl II tend	mnd retro	BSSO/	13.3
80	4.95	op	-	R: Cl II L: Cl II	VME, mnd defic, mx transv deficiency	3 piece LF I, genio/ rigid	7.6

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
81	1.8	op	-	R: Cl I L: Cl I	apertogn, mnd retro, mx hyperpl	LF I BSSO, genio/ rigid 9	8.6
82	3.43	+	-	R: Cl I L: Cl I	mx hyprpl, apertogn, md retro, TM internl derangemnt	BSSO, LF I/ rigid 9	9.9
83	2.4	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid	8.1
84	2.2	+	-	R: Cl I L: Cl II tend	mnd retro bilat TM internal derangmnts	BSSO, genio, bilat arthrsc, rigid	6.8
85	1.45	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid	7.9
86	3.2	+	-	R: Cl I L: Cl I	VME	LF I/ rigid	8.1
87	3.5	+	-	R: Cl II tend L: Cl II	md retro, VME	LF I, BSSO/	11.5
88	1.9	+	-	R: Cl I L: Cl I	mnd prog	BSSO/	9.1
89	4.47	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid	6.1
90	4.28	op	-	R: Cl II L: Cl II tend	mx hyprpl, mnd retro	2 piece LF I, BSSO, genio/ rigid 10	8.7
91	1.0	+	-	R: Cl I L: Cl I	mnd prog	IVRO/	15.11

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
92	4.55	+	-	R: Cl II L: Cl II	mnd retro, ant displ discs, mx hyprpl	LF I, BSSO, bilat arthrpl & menisc repairs	8.10
93	3.2	+	-	R: Cl I L: Cl III	mnd retro	BSSO/ rigid 7	9.1
94	2.95	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid	7.4
95	1.55	0	-	R: Cl I L: Cl I	mx hyprpl, mnd retro, apertogn	BSSO, LF I/ rigid 8	9.1
96	5.75	op	-	R: Cl II tend L: Cl II tend	mx retro, mnd prog, apertogn; 2nd surg: mx constr & apertogn	LF I with wires & BSSO, genio/ rigid 16 2nd srg: 2 piece LF I/ rigid	10.2 then 8.6
97	3.7	op	-	R: Cl II tend L: Cl II tend	mx hyperpl, mnd retro, apertogn, severe bilat condylar resorption	3 piece LF I, extroral invrt-L osteos with hip grafts/ rigid 22	6.7
98	3.9	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid	6.7
99	0.93	+	-	R: Cl I L: Cl III tend	mnd prog	IVRO/	10.1

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
100	1.18	+	-	R: Cl I L: Cl I	mnd prog	BSSO/	10.7
101	4.63	+	-	R: Cl II tend L: Cl I	mx hyperpl, md hypopl, dev septum	2 piece LF I, sptplsty, trbnctmy, nasal rcnstrct genio/ rigid	6.10
102	1.03	0	-	R: Cl I L: Cl I	mnd prog	BSSO/ rigid 10	9.6
103	1.95	+	-	R: Cl II L: Cl I	mx post excess, mx prog, mnd retro, laterogn	LF I, BSSO/ rigid	7.3
104	1.88	+	-	R: Cl III tend L: Cl I	mx retro, mnd prog	LF I, IVRO/ rigid 8	6.8
105	8.45	+	-	R: Cl II L: Cl II	mx hyperpl, mnd retro	LF I, BSSO/ rigid 17	10.6
106	1.5	0	-	R: Cl III tend L: Cl III tend	mnd prog, mx hypopl	mx proplst onlays, invrt-L osteos/ retx'd with 3 piece LF I/ rigid	9.1 then 2.4

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
107	3.8	+	-	R: Cl II tend L: Cl II tend	mnd retro, bilat disc dislocat	BSSO, genio/ rigid bilat TM arthrosc & disc repstion	7.2
108	1.85	+	-	R: Cl I L: Cl II	mnd prog	IVRO/42	15.8
109	2.6	op	-	R: Cl II tend L: Cl II tend	VME, mnd retro, apertogn	2 piece LF I, BSSO, genio/ rigid 10	9.6
110	3.3	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid	9.6
111	3.6	+	-	R: Cl I L: Cl I	mnd retro, TM dysfnct	BSSO	10.6
112	2.85	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 8	8.6
113	1.75	+	-	R: Cl III tend L: Cl III	mnd retro, TM dysfnct	BSSO/ rigid 10	9.8
114	1.8	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 9	9.5
115	4.15	+	-	R: Cl I L: Cl I	mnd retro	BSSO, genio/4	7.5
116	2.85	op	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 16	9.6
117	4.45	+	-	R: Cl I L: Cl III tend	mnd retro	BSSO/ rigid 10	9.6

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
118	5.0	op	-	R: Cl II L: Cl II	VME, mnd retro	LF I, BSSO/ rigid	8.7
119	2.05	+	-	R: Cl I L: Cl I	mnd prog	BSSO/	9.6
120	1.2	+	-	R: Cl I L: Cl I	mx hypopl	2 piece LF I/ rigid 9	9.5
121	2.75	+	-	R: Cl II L: Cl II tend	mnd retro, mnd vert deficiency	BSSO, genio/ rigid	6.7
122	1.5	+	-	R: Cl I L: Cl I	mnd retro	BSSO/ rigid 10	9.5
123	2.7	+	-	R: Cl I L: Cl I	mnd retro, VME, apertogn	2 piece LF I, BSSO/	10.9
124	3.75	+	-	R: Cl III tend L: Cl I	mnd retro	BSSO/28	10.5
125	2.45	+	-	R: Cl I L: Cl I	mnd prog, mx hypopl	IVRO, max proplast implnts/ 21	9.5
126	1.55	+	-	R: Cl I L: Cl I	mnd prog	BSSO/28	9.6
127	4.0	+	-	R: Cl I L: Cl I	mnd retro, TM dysfnct	BSSO/	10.7
128	4.6	+	-	R: Cl I L: Cl I	mnd prog	BSSO/ rigid	9.7

Pt #	OJ (mm)	OB	Post X-Bite	Canines	Dx	Surg/Fix (days)	F/U (yr.mo)
129	1.55	+	-	R: Cl II tend L: Cl I	asymmetric VME, mnd deficiency apertogn	LF I, BSSO, L turb outfx, septal reduct	8.5
130	2.45	0	-	R: Cl III tend L: Cl I	VME, mnd retro, apertogn	LF I, sptplsty turb upfx/ rigid	6.11
131	2.73	+	-	R: Cl II L: Cl II	mnd retro	BSSO/ rigid	6.5
132	5.35	+	-	R: Cl I L: Cl I	mnd retro	BSSO/	13.5

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