SURGICAL RECOVERY AND PATIENT COST ASSOCIATED WITH TEMPORARY SKELETAL ANCHORAGE TREATMENT OF OPEN BITE

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ABSTRACT

JON W. SILCOX: Surgical Recovery and Patient Cost Associated with Temporary Skeletal Anchorage Treatment of Open Bite
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Surgical sequelae, recovery and cost associated with the surgical placement of mini-plate temporary skeletal anchorage devices (TSADs) and maxillary osteotomy were reported. Sequelae and recovery were evaluated using daily questionnaires which were designed to assess the patients’ perception of recovery in four main areas: general activity, oral function, pain, and other symptoms encountered shortly after surgery. Comparisons in each area of substantial interference and median day to recovery between the two groups were calculated. Cost and time comparisons were made from data of records from two consecutively treated groups: patients who received maxillary osteotomy and patients treated with TSADs. Median patient cost and time were calculated and compared. In all areas investigated, the cost, time and recovery associated with surgery for open bite correction were considerably greater for the maxillary osteotomy group than for the skeletal anchorage group.
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CHAPTER I

LITERATURE REVIEW

Open Bite Malocclusion

As might be expected, the etiology of open bite malocclusion has been reported to vary, but a number of factors have generally been associated with the problem. Some of these include unfavorable growth pattern, digit sucking habits, abnormal tongue function or posture, nasal airway obstruction, and mouth breathing. Although open bite, which we will define as a lack of overlap between anterior teeth while in centric occlusion, only occurs in approximately 3.4% of the adult population in the United States, practitioners and clinicians have struggled to obtain a stable treatment result (Proffit, Fields et al. 1998). Multiple etiologic factors may play a role in open bite, but it is interesting to note that open bite malocclusions are 2-3 times more common among Black Americans when compared to their Caucasian and Hispanic counterparts (Proffit, Fields et al. 1998). This may offer some insight as to the genetic role in the development of open bite, but a great number of etiologic factors also may contribute to an open bite malocclusion. Open bites can affect skeletal, dental, and soft tissue relationships, and generally are apparent as a combination of these factors (Proffit and Fields 1993; Noar, Shell et al. 1996). The most common appearance of an open bite is an increased lower face height, an increased mandibular plane angle, with the mandible rotated down and back. This is usually the result of over-erupted posterior teeth or a morphologic difference in the vertical
relationships of the posterior maxillary alveolus. In a cephalometric study of 13 “skeletal” open bite patients, Frost and associates compared the position of skeletal structures to a control group of 19 patients with Angle Class I dental relationships and good dentoalveolar proportions (Frost, Fonseca et al. 1980). In the open bite patients, a greater distance was noted from the palatal plane to the apex of maxillary first molars indicative of posterior vertical maxillary excess or over-eruption of posterior teeth. They concluded that this type of vertical dentoalveolar dysplasia was related to a bite-opening rotation of the mandible, resulting in an increased mandibular plane angle, a reduced SNB angle and a greater lower anterior facial height as is typically seen in open bite patients. Some authors have postulated that skeletal open bites show more molar eruption than do those considered to be dental open bites (Cangialosi 1984). This again, may be a reflection of the etiologic factors and how they influence the pattern of malocclusion.

**Treatment of Open Bite with Conventional Orthodontic Mechanics**

Anterior open bite malocclusions create a unique dilemma in conventional orthodontic treatment. Such treatment only allows a situation of reciprocal anchorage for intrusion of teeth. Thus, if one portion of the dentition is to be intruded, the opposing extrusive force is directed at another portion of the dentition. The alternative in conventional orthodontic mechanics is to extrude teeth using the opposing dentition as support. Many attempts at a stable open bite correction using conventional orthodontics have been made with mild success (Lopez-Gavito, Wallen et al. 1985; Shapiro 2002).
Anterior open bite malocclusions have been treated with fixed mechanics and anterior vertical elastics but often the stability of the extruded anterior teeth became an issue (Kim 1987; Rinchuse 1994; Kucukkeles, Acar et al. 1999). Multi-loop Edgewise Archwire (MEAW) techniques have been applied after second or third molar extraction (Kim 1987; Kim, Han et al. 2000). However, it was found that the dentoalveolar changes related to open bite correction using the (MEAW) were mainly the extrusion of upper and lower anterior teeth with some retraction of anterior teeth and minor changes in the occlusal plane (Kim, Han et al. 2000). Extrusion of anterior teeth to correct open bite has been criticized as being unstable and it has been reported that the vertical heights of the anterior maxilla were already increased in the open bite patient (Ellis and McNamara 1984; Janson, Valarelli et al. 2003). Because extrusion of anterior teeth is basic to all of the traditional mechanotherapies for open bite correction, and because the anterior teeth of skeletal open bite are usually over-erupted due to the dentoalveolar compensatory mechanism, the stability of all of these treatment options remains questionable. Also, extruded teeth have been reported to be less stable than intruded teeth (Reitan and Rygh 1994).

Due to the commonly over-erupted posterior teeth and morphologic differences in open bite patients, many clinicians feel that the posterior maxilla is the primary area where treatment should be directed (Schudy 1965; Creekmore 1967). Some feel that if the posterior teeth are intruded, the mandible will translate forward and upward, often improving the profile and may possibly improve the occlusal relationship. Schudy described the important role of excessive vertical growth in the development of sagittal discrepancies (Schudy 1965). He found that a vertical malocclusion, such as open bite,
often leads to a Class II facial appearance and dental relationships. Subsequently, mechanics have been described to combine control of vertical excess and also to advance the mandible with functional appliances (Pfeiffer and Grobety 1972; Pfeiffer and Grobety 1972; Owen 1985). Although patients treated with this combined approach have shown some impressive results, these methods require a very high level of unpredictable patient cooperation for a long period of time, and such mechanics are only fitting in adolescents or the growing population of patients.

**Surgical-Orthodontic Treatment of Open Bite**

The contemporary correction of a vertical maxillary posterior deformity or an open-bite typically involves a LeFort I down-fracture of the maxilla, with superior repositioning of the maxilla subsequent to removal of bone from the lateral walls of the nose, sinus, and nasal septum. This can be accomplished by superiorly repositioning the maxilla as one piece, or split into segments. The face height then decreases as the mandible autorotates upward and forward. These changes are usually welcomed as they often improve the profile and dental relationships. Maxillary osteotomy treatment has nearly become the standard of care in treating open bite patients and has been shown to have fair to good success and stability (Denison, Kokich et al. 1989; Proffit, Bailey et al. 2000; Swinnen, Politis et al. 2001). Many clinicians have come to recognize the shortcomings of orthodontic treatment alone in the care of open bite patients and have turned specifically to a surgical-orthodontic approach. Subtelney and Sakuda examined twenty-five apertognathic subjects and concluded that at the time of the study, treatment by orthodontic means alone may be impossible and that the best treatment for every
subject would include combined orthodontic and maxillary surgical therapy (Subtelny and Sakuda 1964).

Historically, open-bite closure through counterclockwise rotation of the mandibular distal segment and intermaxillary wire fixation has not been employed because of the instability associated with this technique. With the development of rigid fixation, some authors have reported the ability to close anterior open bite discrepancies in the mandible using a bilateral split osteotomy to autorotate the mandibular distal segment counterclockwise. Joondeph and Shapiro reported on the stability of open bite closure with bilateral sagittal split osteotomy (BSSO) and subsequent counterclockwise autorotation of the mandible (Joondeph and Bloomquist 2004). However, these authors referenced only one publication which reported the long-term stability of the mandibular procedure. This article was referenced as being “in press,” but upon investigation, this referenced article was never found to be published in the literature. No other data have been published to suggest treatment of open bite malocclusions using a BSSO and counterclockwise rotation of the distal segment is a viable and stable treatment approach.

Recovery/Morbidity Related to Surgical-Orthodontic Treatment

Recovery following orthognathic surgery is multifaceted: It may involve overcoming the immediate sequelae of surgery such as nausea and swelling, the resolution of discomfort and pain, returning to normal oral function, and regaining the ability to carry on with a usual lifestyle and activity level.

Following orthognathic surgery, recovery to normal function takes time. Phillips et al found that only half of the patients felt they had returned to previous levels of
activity at 4 weeks post-surgery, and only 70% felt that way at 6 weeks (Phillips and Bennett 2000). Two or more years following surgery, fewer than 10% reported that hospital procedures had not been explained or that they did not know what to expect after being released from the hospital. But approximately one third said they had unexpected difficulty with the post-operative period, and the memory of this was still vivid two years later (Phillips 1999).

Return to normal activity has been used as an indicator of recovery following orthognathic surgery. In a recovery study consisting of 36 patients, subjects reported their recovery period based upon when they were able to return to work or school and to full activity (Dickerson, White et al. 1993). Twelve of the 36 patients had isolated Le Fort I osteotomies (LFI). At 2 weeks postoperatively, none of the LFI group had returned to work. By 3 to 4 weeks, nearly one half of the LFI group still had not returned to work or school. Hemoglobin, hematocrit, weight, and vital signs were also recorded preoperatively and for 6 weeks postoperatively. The LFI group was found to have a larger mean estimated blood loss, length of operation, and weight loss than the group consisting of patients who received a bilateral sagittal split osteotomy correction. It may be postulated that these sequelae may have an impact on overall recovery following maxillary osteotomy.

Neuwirth et al recorded the difference in recovery among orthognathic surgery patients that received autologous blood transfusions and those that did not (Neuwirth, White et al. 1992). Although the primary interest was to describe the differences in these two groups, they reported that 14 of the 46 patients studied (30%) had not returned to pre-surgical activity levels 6 weeks following surgery.
In a retrospective study, the perceptions of 327 patients regarding the delivery of orthognathic surgery were recorded (Williams, Travess et al. 2004). Although most participants reported that they were well-informed about what to expect during treatment, many reported that the symptoms of pain, swelling, or difficulty in eating that they experienced immediately post-operatively were worse than expected. A third of the subjects also reported that it took them longer to recover from the operation than they had anticipated. In another study, 10% of the 90 respondents reported they would not re-elect to have the surgical treatment (Flanary and Alexander 1983). Reasons for dissatisfaction varied, although all had in common the occurrence of unanticipated post-surgical events.

Murphy, while an orthodontic resident, underwent bimaxillary orthognathic surgery and documented her experience in diary fashion (Murphy 2005). She reported on changes in speech, ability to chew food and consequences of experiencing paraesthesia and swelling.

Although the recovery following orthognathic procedures varies, patients usually experience considerable facial edema. Following orthognathic procedures, the severity of facial edema is often not correlated with the degree of difficulty of the procedure. Day and Robert used an optical surface laser scanner to record and quantify the facial soft tissue changes following orthognathic surgery (Day and Robert 2006). They reported that following a Le Fort I osteotomy, the surgical edema peaked on the second or third post-surgery day and much of it resolved within 2 weeks. Recovery of touch discrimination is also variable. Return of sensation may be rapid, occurring in a few weeks, or may continue over 6 to 12 months in Le Fort I osteotomy procedures and often
does not correlate with the degree of difficulty of the osteotomy procedure (Karas, Boyd et al. 1990; Proffit, White et al. 2003).

**Treatment of Open Bite with Skeletal Anchorage**

Orthognathic surgery offers a means of impacting or intruding posterior teeth in a way not possible by conventional orthodontic treatment alone. However, recently, molar intrusion using temporary skeletal anchorage devices (TSAD) has been developed as a new strategy for open bite treatment. Such devices provide absolute anchorage and overcome the limitation of reciprocal anchorage and allow pure intrusion without the opposing effects on other parts of the dentition.

Several methods to acquire absolute or bone anchorage have been reported. Endosseous palatal implants have been used to resist the counteraction of orthodontic tooth movement, but they require complicated surgery for both placement and removal, involve significant costs, and cannot be immediately loaded (Odman, Lekholm et al. 1988; Turley, Kean et al. 1988; Prosterman, Prosterman et al. 1995).

Mini- or micro-screws, which are placed by penetrating directly through the mucosa, have been advocated for the closure of open bite malocclusions by intruding posterior teeth (Park, Kwon et al. 2004; Xun, Zeng et al. 2007). However, these screws are placed in the alveolus and may interfere with tooth root movement and require removal and placement in a different location mid-treatment.

Titanium mini-plates, analogous to surgical fixation plates, have become an attractive option in the treatment of open bite. In original reports in animals and in humans, mini-plates were applied to the mandibular corpus area and used as anchorage...
for intrusion of the mandibular posterior dentoalveolar segment for the correction of anterior open bite (Umemori, Sugawara et al. 1999; Ohmae, Saito et al. 2001). Sugawara et al. used a specially designed skeletal anchorage system (SAS) for correction of anterior open bite by intruding the mandibular molars in humans. Other authors have reported zygomatic anchorage as an alternative form of maxillary posterior anchorage, especially as a means of correcting an open bite (Melsen, Petersen et al. 1998; De Clerck, Geerinckx et al. 2002; Sherwood, Burch et al. 2002; Erverdi and Keles 2003). These studies describe the zygomatic buttress area as a valuable anchorage site to get effective intrusion of the maxillary posterior segment.

Several case reports and case series describing maxillary posterior tooth intrusion using mini-plate temporary skeletal anchorage have been reported, but most studies were case reports of fewer than 5 patients describing treatment possibilities or successful treatment outcomes in qualitative terms (Sherwood, Burch et al. 2002; Erverdi, Keles et al. 2004).

A recent study compared the treatment outcomes in open bite patients when using 2-jaw, maxillary and mandibular osteotomy procedures and when using skeletal anchorage for molar intrusion (Kuroda, Sakai et al. 2007). The authors compared pre-treatment and post-treatment lateral cephalograms of ten skeletal anchorage open bite patients and thirteen orthognathic surgery open bite patients. It was determined that there were no significant differences in treatment results between the two groups. The authors concluded that molar intrusion using skeletal anchorage is simpler and more useful than 2-jaw surgery in the treatment of severe open bites. Such results appear to be promising toward a skeletal anchorage alternative to orthognathic surgery. However, placement of a
mini-plate also requires a surgical procedure and no studies have been published that compare the surgical experience, sequelae, and recovery associated with mini-plate placement and maxillary osteotomy. Also, no data exists relating the difference in cost between the two procedures.

Recovery Associated with Mini-plate TSAD

Very few studies address the recovery associated with treatment using mini-plate TSADs. Only two studies were found which evaluated patient recovery or perceptions related to implantable devices used for anchorage in orthodontics. Patient and practitioner perceptions’ of miniplate TSAD placement and use were recorded by Cornelis et. al from 97 consecutive patients and 30 orthodontists in two university settings (Cornelis, Scheffler et al. In Press). After one year, 72% of patients reported they did not mind having TSADs and 82% said the surgical experience was better than they expected, with little or no pain. Post-surgical swelling, reported to last about 5 days on average, and cheek irritation reported by nearly one third of patients were the most frequent problems. This group concluded that: miniplates are well accepted by patients and providers, they offer safe and effective anchorage possibilities with a high success rate (92.5%), and few side effects or problems during treatment. A second study reported the acceptance rate of palatal implants in 85 patients (Gunduz, Schneider-Del Savio et al. 2004). Questionnaires were completed by patients at some point in treatment following the loading of the palatal implant. These authors reported that nearly 95% of patients were satisfied with their treatment and 86% would recommend the palatal implants to other patients.
Other authors have mentioned the sequelae and recovery process in the use of TSADs, but none have specifically reported on these items. In a study of 44 zygomatic miniplates in 25 different patients, the authors reported the patients tolerated the surgery and treatment of miniplates well (Chen, Hsieh et al. 2007). However, no measurements of recovery or sequelae were employed in this study. In another study of ten patients, the authors refer to the surgical placement of miniplates as a minimally invasive procedure, but again, did not report the sequelae and recovery associated with the procedure (Erverdi, Keles et al. 2004). Other authors reported mild facial swelling for a week after the operation and also noted, but did not explain, that it was necessary to take antibiotics and brush carefully following the surgery (Zhou, Ding et al. 2007). Miyawaki et. al reported a generalized complaint of swelling and discomfort associated with placement of miniplate TSADs were disadvantages when compared to the use of mini-implants for anchorage in orthodontic treatment (Miyawaki, Koyama et al. 2003). These authors felt that the use of a flap surgery, regardless of the type of TSAD placed was the predominant factor associated with discomfort and swelling. No data was presented to support these claims. Obviously, data are lacking relating to the sequelae and recovery following placement of mini-plate TSADs.

Cost Associated with Mini-Plate Skeletal Anchorage

Given the novelty of the use of temporary skeletal anchorage in orthodontics, little data have been published that documents the cost in both time and money associated with such treatment. Erverdi and Sherwood both reported time of active intrusion of posterior teeth, but did not evaluate surgical time or cost related to the placement of the
TSADs (Sherwood, Burch et al. 2002; Erverdi, Keles et al. 2004). Other authors have estimated the time required for surgical placement of TSADs, but no studies have reported data on this topic (Sherwood, Burch et al. 2002; Erverdi, Usumez et al. 2006; Chen, Hsieh et al. 2007). In a systematic review of the literature, no data were discovered documenting cost in any form of currency associated with the treatment and use of temporary skeletal anchorage of any type.

Cost of Surgical-Orthodontic Treatment

Some attempts to quantify costs related to orthognathic surgery have been undertaken. As an example, Lombardo et al. identified the costs of Le Fort I and bilateral sagittal split osteotomies (Lombardo, Karakourtis et al. 1994). These authors reported that for Le Fort I osteotomies, average patient charges ranged from $3538 to $6784 expressed in dollars in the year 1992. The surgery-related costs in this study seem to be substantial, but it must be emphasized that the figures quoted are patient charges and may not reflect the true cost of treatment. Kumar et al. reported that orthodontic costs may comprise a substantial proportion of the total cost of orthognathic treatment and there is currently a lack of information on the orthodontic costs in relation to the total cost of orthognathic care (Kumar, Williams et al. 2006). These authors studied the cost, rather than patient charges, of orthognathic treatment for 352 subjects in 11 different hospital units in south-west England. They calculated cost as it related to the number of visits in out-patient clinics, laboratory costs, orthodontic consumables, surgical consumables, capital and overhead costs, and staff costs. They reported the average total cost in the year 2000 to be €6293.72 (approximately $8140 US dollars). Of this amount, nearly a
quarter was related to routine orthodontic costs. Surgical-orthodontic treatment of anterior open bite malocclusion was reported to be €6593.33 (approximately $8527 US dollars). This amount was higher than any other type of malocclusion correction.

Reporting on the cost of surgical-orthodontic treatment, Panula also found the correction of skeletal open bite constituted the most costly treatment. (Panula, Keski-Nisula et al. 2002)

While studying the impact of clinical practice patterns on hospital charges for orthognathic surgery, Lombardo discovered charges attendant to the surgical procedure (anesthesia, operating room, supply, and recovery) were just over half of total charges in 1985 (Lombardo, Karakourtis et al. 1994). However, by 1992 these components escalated to 80% of the total charges related to orthognathic surgery.

No recent reports of the current costs associated with orthognathic surgery in the United States have been published.

**Surgery Associated Patient-Time**

Very little data exists depicting the amount of patient-time that is required for either a maxillary osteotomy procedure or placement of mini-plate temporary anchors. In a study of 44 mini-plates in 25 different patients, it was determined most surgical placements required 25-30 minutes for each TSAD, but no means of measurement was employed (Chen, Hsieh et al. 2007).

Multiple studies were found which investigated the number of visits and months in treatment of patients who underwent orthognathic surgery (Proffit and Miguel 1995; Dowling, Espeland et al. 1999; Luther, Morris et al. 2003). However, no studies were
found to report patient-time associated specifically with orthognathic surgery or placement of TSADs in terms of appointments surrounding the surgical event or time in the operating room and hospital.

Medical Diaries

Medical diaries have been used to document the health related quality of life and recovery following surgery. In studies with this approach, subjects typically report complications and symptom resolution at fixed intervals, usually daily in a prospective fashion. For example, Tan et al. and Parsons et al. used medical diaries to compare postoperative recovery following tonsillectomy using different surgical devices (Parsons, Cordes et al. 2006; Tan, Hsu et al. 2006). Young et al. reported on the recovery associated with laparoscopic cholecystectomy in either a 23 hour or an 8 hour facility using a medical diary method (Young and O’Connell 2001). In dentistry, White et al. and Conrad et al. used a daily diary to study recovery of patients who had third molars removed (Conrad, Blakey et al. 1999; White, Shugars et al. 2003). Phillips et al., Foy et al., and Stavropoulos et al. used diaries to assess risk factors associated with prolonged recovery following third molar extractions (Phillips, White et al. 2003; Foy, Shugars et al. 2004; Stavropoulos, Shugars et al. 2006).

There is some concern that patients do not comply with diary protocols, thus possibly invalidating the benefit of diary data. Some authors advocate the use of electronic diaries with incorporated compliance-enhancing features (Stone, Shiffman et al. 2003). Electronic diaries have been shown to produce more accurate data, but they may be cost prohibitive and not suitable for all studies (Piasecki, Hufford et al. 2007).
A fundamental benefit of diary methods is that they permit the examination of reported events and experiences in their natural, spontaneous context, providing information complementary to that obtainable by more traditional designs (Reis 1994). Another benefit is a reduction in the likelihood of retrospection, achieved by minimizing the amount of time elapsed between an experience and the account of the experience. These benefits produce data that aids in treatment evaluation, patient education, and proper treatment planning.
REFERENCES


CHAPTER II

MANUSCRIPT

Surgical Recovery and Patient Cost Associated with Temporary Skeletal Anchorage Treatment of Open Bite

INTRODUCTION

The use of temporary skeletal anchorage is an evolving clinical technique that has an intriguing potential to facilitate the treatment of “difficult to manage” malocclusions. In the past, malocclusions such as open bite could be definitively treated only by orthognathic surgical correction. The effectiveness and stability of open bite treatment using a Le Fort osteotomy has been well documented (Bailey, Phillips et al. 1994; Swinnen, Politis et al. 2001). Multiple reports of open bite closure with the use of screw or mini-plate anchorage have now been published (Sherwood, Burch et al. 2002; Sugawara, Baik et al. 2002; Park, Kwon et al. 2004). The purpose of this investigation is not to validate the success or effectiveness of open bite treatment using skeletal anchorage, but to compare this type of treatment to the current standard approach of treatment (maxillary osteotomy) in terms of recovery and cost. If temporary skeletal anchorage proves to be as effective and stable as maxillary osteotomy for posterior intrusion, the clinical implications will be significant as both practitioners and patients will then have a less invasive and less cost restrictive treatment option.
Planning treatment for patients with anterior open bite resulting from vertical discrepancy of the posterior maxillary and/or mandibular units can be complex. Variations in the rate and amount of growth in both the maxillary complex and the mandibular condyles influence vertical development. While it is sometimes possible to identify specific etiologic factors, in many instances neither the causative factors nor the full extent of the deformity are apparent in the preadolescent. Unfortunately, the severity of the condition frequently increases with continued vertical growth into early adulthood (Schudy 1965; Isaacson, Zapfel et al. 1977). The most usual morphological pattern seen in open bite patients is increased vertical development of the posterior maxillary dentoalveolar unit, resulting in an increased mandibular plane angle and an increased anterior lower facial height (Schudy 1965; Sassouni 1969; Frost, Fonseca et al. 1980; Proffit and Fields 1993). Not surprisingly, clinicians have long felt that the primary area where treatment should be directed is therefore the posterior maxilla (Schudy 1965; Creekmore 1967; Frost, Fonseca et al. 1980).

Treatment options for patients with open bite must be related not only to the location, extent of the deformity, but also to the patient’s age. A number of non-surgical approaches have been described, but these usually require high levels of patient compliance and must generally be continued over an extended period of time until vertical growth is complete (Nielsen 1991; Rinchuse 1994; Woodside and Aronson 1997). Even then, the long-term stability of orthodontic correction of open bite has been disappointing, with a high percentage of patients showing significant relapse, generally associated with a continued increase in posterior maxillary height and downward and backward rotation of the mandible (Burford and Noar 2003). These changes, particularly
when coupled with relapse of extruded incisors can lead to significant relapse and bite-opening (Lopez-Gavito, Wallen et al. 1985).

The lack of stability of orthodontic correction of open bite led to the development of surgical techniques for treatment, including the contemporary approach: Le Fort I down fracture and superior positioning of the maxilla following removal of bone from the lateral wall of the nose and nasal septum (Bell and McBride 1977). The maxilla may be positioned superiorly as one piece or in multiple segments. In so doing, the face height decreases, the mandible rotates upward and forward, and the open-bite is closed. Although longitudinal studies show surprising amounts of change beyond the one year period, relapse of the open bite appears unlikely for the majority of these patients (Proffit, Bailey et al. 2000). Five-year follow up identifies approximately 30% of patients as having continued downward movement of the maxilla and downward backward rotation of the mandible, very similar to the pattern of growth that produced the long-face/open-bite condition initially (Bailey, Phillips et al. 1994). Despite this tendency for continued skeletal change, in the long term, the overbite is as likely to increase as it is to decrease, presumably because of continued compensatory eruption of the incisors (Proffit, Bailey et al. 2000). Although traditionally reported as a less stable procedure (Epker and Fish 1977), open bites may also be closed using a mandibular sagittal split osteotomy and upward rotation of the distal segment of the mandible. The introduction of rigid fixation has reportedly increased the stability of this surgical approach, but the long term success is currently not well documented (Joondeph and Bloomquist 2004).

The first reported use of temporary implantable devices to serve as skeletal anchorage for tooth movement was in 1945 with vitallium screws placed in the
mandibular rami of dogs to retract canine teeth without disturbing the position of the molars (Gainsforth and Higley 1945). Although tooth movement was limited due to the loosening of the implants, this work set the stage for further development of temporary skeletal anchorage devices (TSAD) in orthodontics. Relatively recent clinical advances have again placed interest on temporary skeletal anchorage devices which do not significantly move when subjected to orthodontic forces and allow tooth movements beyond those traditionally observed. The availability of absolute anchorage beyond the dental units, with devices that require very little in terms of compliance from patients, and that can be used as readily in adults as adolescents has changed the options for orthodontic treatment.

Several types of temporary skeletal anchorage devices are currently in use. Palatal implants and onplants, which are placed in the denser and thicker bone of the palate in prepared sites under the mucosa, are uncovered and loaded later following osseo-integration and frequently need to be removed by trephine. Mini- or micro-screws, analogous to oral surgery fixation screws, are placed by penetrating directly through the attached mucosal tissue and generally loaded within 4 weeks of placement. These small titanium screws generally do not become osseo-integrated and can be easily removed without surgery, although some clinicians feel that mini- or micro-screw implants do become osseo-integrated if allowed to heal submucosally for three months prior to surgical uncovering and loading (Kanomi 1997). Mini-plates, modifications of the traditional fixation plates used in orthognathic surgery, are usually placed in the zygomatic buttress and require a surgical mucoperiosteal flap for both placement and removal. They have an extension arm which exits the mucosa to allow attachment to
orthodontic appliances. Mini-plates are generally considered to be mechanically retained and usually do not become extensively osseo-integrated over the relatively short time they are used.

Case reports and experimental animal model data have demonstrated the potential of temporary anchorage devices as absolute anchorage for posterior tooth intrusion in the treatment of open bite, thereby providing an attractive alternative to surgical correction (Umemori, Sugawara et al. 1999; Sherwood, Burch et al. 2002; Erverdi, Usumez et al. 2006). To date, only anecdotal reports on the stability of open-bite correction following the use of temporary skeletal anchorage devices exist (Sugawara, Baik et al. 2002), with no long term reports on physiologic adaptation to this type of treatment. Preliminary reports on patient perception of the use of mini-plates are only now appearing in the literature but do suggest broad patient acceptability with little associated morbidity. Findings from a prospective study of 97 consecutive patients treated with mini-plates reported: the principal adverse outcome was swelling of the cheeks generally persisting for about 5 days following the surgery; greater than 50% of the patients reported no pain associated with anchor placement or removal; 100% found mini-plates to be more tolerable than headgear; and more than 50% reported their experience with dental extractions was worse than their experience with mini-plates (Cornelis, Scheffler et al. In Press).

Mini-screws have been used to provide anchorage for posterior tooth intrusion, but present a challenge in placement to create effective force application while remaining clear of tooth roots and not becoming submerged under unattached oral mucosa. Problems have been described with mini-screw use, including screw fracture (Buchter,
Wiechmann et al. 2006), loosening under loading (Liou, Pai et al. 2004), or impingement upon roots either at the time of placement or during treatment (Park, Lee et al. 2003).

Management of an open bite with mini-screws requires careful initial placement and may involve repositioning the devices to allow intended tooth movements and avoid an encounter with tooth roots. Mini-plates, placed at a distance from tooth roots, offer the advantage of a reduced risk of root impingement and are associated with a lower failure rate than mini-screws. (Buchter, Wiechmann et al. 2006)

The introduction of any new technology or technique should be accompanied by systematic evaluation of not only the effectiveness of the new treatment method, but also its associated morbidity and side effects. Such comparisons should be made against current practices or the best available alternative treatment, which in this case is a Le Fort I osteotomy. Recovery from orthognathic surgery can vary quite markedly, but certain morbidities seem to predominate post surgically, including pain, swelling, bruising and bleeding, restriction of oral function, reduction in feeling of well-being, limitation of social and work/school related activities, and nerve damage or altered sensation (Neal and Kiyak 1991; Dickerson, White et al. 1993; Williams, Travess et al. 2004; Phillips, Essick et al. 2006). Some of the same sequelae are also experienced by patients following surgical placement of TSAD. Information on the degree to which patients might expect to experience such sequelae following treatment for open bite, either by Le Fort I osteotomy or TSAD, is important if patients are to make a reasonably informed decision about alternative treatment options. In addition, each treatment option carries with it time and financial costs, all of which must be considered as part of the treatment
decision. This is especially important considering the difficulty or inability some patients have in obtaining insurance coverage for orthognathic surgical procedures.

SURGICAL EXPERIENCE AND RECOVERY

Orthognathic surgery-patients at UNC complete a series of recovery diaries consisting of daily questionnaires with 20 questions designed to assess the patients’ perception of recovery in four main areas: general activity, oral function, pain, and other symptoms encountered shortly after surgery. Patients complete these daily questionnaires for three months following surgery. Identical questionnaires were given to a group of orthodontic patients being treated with bilateral mini-plate anchors secured to the zygomatic buttress. These TSAD patients completed the daily health diaries for 14 consecutive days beginning the day following surgical placement of mini-plates and at twenty-one days following placement.

To compare the surgical experience of open-bite patients treated with maxillary osteotomy and patients treated with mini-plates, two groups of patients were identified. The first consisted of patients treated by Le Fort I osteotomy who completed the recovery diaries (21 patients, 13 females and 8 males). These patients were treated by three different oral surgeons, but always in the same hospital setting. The mean age of this group at the time of surgery was 26.2 years with a range of 17.4 to 39.7 years. 12 had superior repositioning of the maxilla as one segment, 4 had a two-segment surgery, and 5 required three segments. No other surgical procedures were completed.
The TSAD group consisted of 20 patients (13 females and 7 males) treated in the Orthodontic Department at the School of Dentistry at UNC who completed the recovery diaries. These patients all underwent bilateral mucoperiosteal flap surgery for placement of temporary skeletal anchors with fixation to the zygomatic buttress. In addition, one patient had two mandibular mini-screws placed and one patient received bilateral mandibular bone anchors at the time of zygomatic anchor placement. The mean age of this group at the time of placement of TSAD was 23.4 years with a range of 10.6 to 44.4 years. Bollard (Surgitec, Bruges, Belgium) anchors were exclusively used with two or three fixation screws in each anchor according to the local bone morphology. All patients were treated under conscious sedation. The procedures were completed in an outpatient setting at the UNC School of Dentistry Department of Oral Surgery by seven different surgeons. Mini-plates were loaded approximately 3 weeks following the surgery.

Patient responses in sections of the questionnaires addressing general activity, oral function and symptoms such as swelling and bruising, were scored on a scale of 1 (no trouble) to 5 (lots of trouble) and sections addressing discomfort and pain used a scale of 1 (No discomfort) to 7 (Worst discomfort imaginable). For questions that used a scale from 1-5, substantial interference was defined as a 4 or 5 response. For questions that used a 1-7 scale, substantial interference was defined as a response from 5 to 7. Comparisons of substantial interference were made from questionnaires completed on days one through fourteen and on day twenty one. Median day to recovery was interpreted as the first day when 50% of respondents report little or no problem (1 or 2 response). For calculations of median day to recovery, questionnaires from day 1-90
were used for the osteotomy group and questionnaires from day 1-14 and day 21 were used for the TSAD group. In each of the figures (Figures 1-3), the percent of patients that reported substantial interference in each category is plotted by day (a), and the distribution of median day to recovery is shown in quartiles (b) for both the osteotomy and the TSAD groups.

**General Activity**

The responses in the area of general activity were considerably different between the maxillary osteotomy group and the TSAD group, but both groups reported substantial interference due to the surgical procedure in their regular routine, social life, and recreation (Figures 1 and 2). Figure 1 shows that greater than 50% of patients in the maxillary osteotomy group were not able to resume their normal daily routine for nearly a week following surgery, while less than 10% of those in the skeletal anchorage group reported substantial interference in performing daily activities, and this interference only lasted from post-surgery day one to day four. The median number of days to recovery (the first day 50% of patients reported little or no problem) in the three areas of general activity is shown in Figure 2.

**Oral Function**

All of the respondents in both groups reported substantial interference with normal chewing and most reported some difficulty eating and opening their mouth immediately following the surgical procedure. More than 60% of the osteotomy group reported substantial interference in eating over the entire 21 days recorded and more than 70% of the osteotomy group also experienced considerable difficulty chewing throughout
the time period. A minority of the skeletal anchorage group reported substantial interference in eating and chewing that persisted for five days or less following the surgical event (Figure 3). In the areas of eating, chewing and opening, the median day to recovery for the maxillary osteotomy group was at least six times greater than that of the TSAD group (Figure 4).

Pain and Other Symptoms

Patients in both groups reported substantial pain and swelling related to their respective surgical procedure. Nearly 5% of respondents in the maxillary osteotomy group reported that they experienced substantial pain over the 21 day protocol while no patients in the TSAD group reported substantial pain beyond day seven. Patients in the osteotomy group reported substantial problems with bleeding while none of the skeletal anchorage group reported such problems. At some point following surgery, the majority of both groups reported substantial swelling (Figure 5) but this generally subsided prior to day 4 in the TSAD group and prior to day 12 in the osteotomy group (Figure 6).

COSTS ASSOCIATED WITH SURGERY

In comparing treatment options for open bite correction, it is important to consider the difference in patient-costs incurred both in time and money. Due to the relative novelty of use of temporary skeletal anchorage devices in orthodontics, little data have been published that documents cost, in time or money, related to the placement of such devices. Cost involved in orthognathic surgical treatment, on the other hand, has been more extensively examined. Most interest has been placed on the increase in
hospital related charges involved in orthognathic surgery (Lombardo, Karakourtis et al. 1994), but some data to quantify costs involved in surgical-orthodontic treatment have been published (Lombardo, Karakourtis et al. 1994; Dolan and White 1996; Kumar, Williams et al. 2006). Although surgical costs vary according to demographics and provider, the surgical correction of open bite often constitutes the most costly orthognathic treatment (Panula, Keski-Nisula et al. 2002).

Data were obtained from the records of two consecutively treated patient groups from the patient database found in the UNC Department of Orthodontics. Group one included seven patients that received a maxillary Le Fort I osteotomy in one, two, or three segments with no other surgical procedures. All patients were treated as in-patients in a hospital setting. Group two consisted of ten patients treated with bilateral zygomatic modified mini-plates (TSAD) as part of their orthodontic treatment plan. All patients were treated in an out-patient clinical setting. Accounting records, billing statements and surgical notes were collected from UNC hospital and UNC School of Dentistry for each subject. Patient cost associated with radiographs, surgeon’s fee, anesthesiologist fee, anesthesia/sedation, operating room services, hardware (fixation plates/screws), recovery room, private hospital room, lab/pathology, and pharmacy was recorded. Patient time associated with pre-operative clinic visits, operating room, recovery room, over-night hospital stays, post-operative visits, and placement or removal of hardware was also recorded. Median patient cost and time were calculated.
**Surgery Associated Patient Cost**

When all variables were considered, the median total surgical cost was approximately 12 times higher than the median total cost sustained by the group treated with skeletal anchorage ($23,071 and $1,925, respectively). A summary of the patient costs associated with maxillary osteotomy and temporary skeletal anchorage is given in Table 1.

**Surgery Associated Patient Time**

The median patient time associated with a maxillary osteotomy procedure was again found to be nearly 12 times greater than that required for the temporary skeletal anchorage group (36.1 hours and 3.00 hours, respectively). These data are summarized in Table 2. These results do not reflect time to full recovery nor when the patient returned to normal routine.

**CASE REPORT**

For many patients, the cost and recovery associated with orthognathic procedures are serious considerations. The patient shown in Figure 7 was referred to be treated with a maxillary Le Fort osteotomy for her chief complaint of TMD secondary to an open bite. Before initiating treatment, the patient asked to discuss the surgical procedure and recovery with another person who had experienced a maxillary Le Fort osteotomy. She then made the decision to undergo the, at the time, novel approach of treatment using zygomatic temporary skeletal anchorage to intrude the posterior teeth and close the open bite rather than by means of the initially proposed orthognathic surgical approach.
Bilateral zygomatic mini-plates were placed and maintained for approximately 22 months. Intrusion of the posterior teeth was primarily achieved using elastic thread from the anchor to the upper archwire after bonding only upper canine to second molar bilaterally. A transpalatal arch on the upper first molars was used to resist facial tipping of the posterior teeth. Only after proper overbite was achieved were the maxillary incisors and lower teeth bonded for final detailing. Total treatment time was 26 months and the patient reported to be very satisfied with her decision to not have undergone orthognathic surgery.

Final photos on the day of debonding and can be seen in Figure 8 and one year retention records are shown in Figure 9. Overall, the patient and doctor were pleased with the outcome and the occlusion has remained stable, without return of TMD symptoms. Structural treatment results are illustrated in the super-imposition from initial to one year post-treatment (Figure 10).

CONCLUSION

In all areas investigated, the cost, time and recovery associated with surgery for open bite correction were considerably greater for the maxillary osteotomy group than for the skeletal anchorage group. Although recovery associated with surgical removal of temporary skeletal anchorage was not included, it has been our experience that the recovery and sequelae associated with removal are considerably milder than the placement of TSADs.

These data do not imply that temporary skeletal anchorage is suitable treatment for all open bite patients. Each patient must be evaluated individually as to the best mode
of treatment. Clinical trials and long-term follow-up of open bite patients treated with
TSAD are currently lacking in the literature, and will be required to ensure predictability,
quality and stability of this type of treatment. However, if the treatment of open bite with
temporary skeletal anchorage is shown to be as effective and stable as maxillary
osteotomy, many patients may benefit from this less costly, less invasive, and less
debilitating approach.
Figure 1
Percent of respondents that reported substantial interference (4 or 5 response) in three areas of General Activity for Skeletal Anchorage (SA) and Maxillary Osteotomy groups (MO).
Figure 2
Descriptive statistics for days to recovery (1 or 2 response) in General Activity for Skeletal Anchorage and Maxillary Osteotomy groups.
Figure 3
Percent of respondents that reported substantial interference (4 or 5 response) in the three designated components of Oral Function for Skeletal Anchorage and Maxillary Osteotomy groups.
Figure 4
Descriptive statistics for days to recovery (1 or 2 response) in three components of Oral Function for Skeletal Anchorage and Maxillary Osteotomy groups.
Figure 5
Percent of respondents that reported substantial interference in Bleeding (4 or 5 response), Swelling (4 or 5 response), and Pain (5 to 7 response) for Skeletal Anchorage and Maxillary Osteotomy groups.
Figure 6
Descriptive statistics for days to recovery (1 or 2 response) in Swelling, Bleeding, and Pain for Skeletal Anchorage and Maxillary Osteotomy groups.
Figure 7
Pretreatment records of a 27.0-year-old female with anterior open bite. Zygomatic mini-plates were used to intrude posterior teeth with a total treatment time of 26 months.

Figure 8
Day of appliance removal showing proper overbite was achieved.

Figure 9
One-year retention records showing overbite has remained closed.
Figure 10
Cephalometric superimposition of initial and one-year post-treatment shows intrusion of maxillary molars with a counter-clockwise rotation of the mandible.
**Table 1**
Patient incurred surgical cost associated with open bite correction using maxillary Le Fort osteotomy and mini-plate temporary skeletal anchorage.

<table>
<thead>
<tr>
<th></th>
<th>Maxillary Osteotomy (n=7)</th>
<th>TSAD (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Range</td>
</tr>
<tr>
<td>Pre-Op Radiographs</td>
<td>$364</td>
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<tr>
<td>Surgeon's Fee</td>
<td>$6500</td>
<td>$4250 - $6700</td>
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<tr>
<td>Anesthesiologist Fee</td>
<td>$800</td>
<td>$800 - $800</td>
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<td>Anesthesia/Sedation</td>
<td>$2,439</td>
<td>$1643 - $2472</td>
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<td>Operating Room Services</td>
<td>$6,236</td>
<td>$5289 - $7654</td>
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<tr>
<td>Hardware (fixation plates/screws)</td>
<td>$4,975</td>
<td>$3497 - $8695</td>
</tr>
<tr>
<td>Recovery Room</td>
<td>$771</td>
<td>$743 - $825</td>
</tr>
<tr>
<td>Private Room</td>
<td>$900</td>
<td>$0 - $1800</td>
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<tr>
<td>Lab/Path</td>
<td>$121</td>
<td>$99 - $184</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>$1,241</td>
<td>$1104 - 1980</td>
</tr>
<tr>
<td>Total Surgical Cost</td>
<td>$23,071</td>
<td>$21,508 - $25,897</td>
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</table>

*Surgical placement and removal included in TSAD figures.

**Table 2**
Patient-hours associated with surgery for open bite correction using maxillary Le Fort I osteotomy and mini-plate temporary skeletal anchorage.

<table>
<thead>
<tr>
<th></th>
<th>Maxillary Osteotomy (n=7)</th>
<th>TSAD (n=10)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Median (hrs)</td>
<td>Range</td>
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<tr>
<td>Pre-Op Consults</td>
<td>0.6</td>
<td>0.5 - 1</td>
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<td>Post-Op Consults</td>
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<td>Total Surgical Suite/OR Time</td>
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<td>2.5 - 5.5</td>
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<tr>
<td>TSAD Surgical Removal</td>
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<td>N/A</td>
</tr>
<tr>
<td>Recovery Room</td>
<td>1.5</td>
<td>1.5 - 2.5</td>
</tr>
<tr>
<td>Private Room (overnight stays)</td>
<td>24.0</td>
<td>0 - 48</td>
</tr>
<tr>
<td>Total Time Assoc w/ Sx (hours)</td>
<td><strong>33.2</strong></td>
<td>10 - 57 hours</td>
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REFERENCES


