

**EFFECTIVENESS AND STABILITY OF ANTERIOR OPEN BITE CORRECTION
USING TEMPORARY SKELETAL ANCHORAGE:
COMPARISON TO SURGICAL OUTCOMES**

by
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A thesis submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Master of Science in the Department of Orthodontics.

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ABSTRACT

J. TURNER HULL: Effectiveness and Stability of Anterior Open Bite Correction Using Temporary Skeletal Anchorage: Comparison to Surgical Outcomes
(Under the direction of Dr. Camilla Tulloch)

The skeletal and dental changes that occur following the intrusion of maxillary posterior teeth with temporary skeletal anchorage (TSA) and the stability of these changes over time were assessed in twelve patients (1 male, 11 females) with anterior open bite. A comparative sample of patients treated with maxillary osteotomy was frequency matched based on age and gender. Lateral cephalograms were obtained before treatment/surgery, at the end of treatment/post-surgery, and at least 6 months following the completion of treatment. All pretreatment measurements except overbite were similar, on average, between the two treatment groups. Positive overbite was achieved for all patients treated with TSA's (Pre-tx OB \bar{x} = -1.0mm, Post-tx OB \bar{x} = 2.7mm). Both groups showed a similarly small average change during the follow-up time period. Overbite correction via intrusion of maxillary posterior teeth using TADs appears to be an effective and stable treatment modality.

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SECTION I

LITERATURE REVIEW

A skeletal anterior open bite due to vertical excess in the posterior maxilla is one of the most difficult malocclusions to treat orthodontically. The preferred treatment of posterior tooth intrusion is not easy to obtain with traditional orthodontic mechanics and a combined orthodontic and surgical intervention is typically utilized for optimal treatment results. The complexity, risks, and morbidity associated with the surgery, and the financial burden to the patient have encouraged a search for alternative clinical approaches to correct vertical posterior maxillary excess leading to anterior open bite. With the recent application of Temporary Skeletal Anchorage, true posterior tooth intrusion can be achieved using traditional orthodontic appliances and a minimally invasive surgical procedure.

Open Bite Malocclusion

The anterior open bite comprises only a small portion of orthodontic patients but, due to the complexities of its treatment, it has drawn much attention from clinicians over the past several decades. The National Health and Nutrition Estimates Survey (NHANES) III taken between the years 1989-1994 estimated the prevalence of anterior open bite, defined as overbite less than 0, to be 3.6% in 8-11 year-olds, 3.5% in 12-17 year-olds, and 3.3% in 18-50 year-olds. Of these individuals, less than 1% had an open bite greater than 2 mm. When

ethnicity was evaluated, it was found that open bites greater than 2 mm were five times more prevalent in blacks than in whites or Hispanics¹. However, this study only evaluated the vertical relationship of the anterior teeth and did not differentiate possible etiologies.

Various etiological factors have been associated with the development of an anterior open bite. These range from vertical skeletal growth discrepancies, abnormal size and function of the tongue, and finger or thumb-sucking habits²⁻⁶. Less common etiologies are total nasal obstruction, abnormalities in muscular growth or function, and arthritic condylar degeneration⁶. There are two general categories of anterior open bite; skeletal and dental. The dental open bite is associated with a normal craniofacial growth pattern in conjunction with proclined incisors, undererupted anterior teeth, normal or slightly excessive molar height, and a digit sucking habit⁶. The treatment of the dental open bite usually is more straightforward and typically involves the extraction of teeth to relieve tooth protrusion. The skeletal open bite has a more complex presentation and is associated with disruptions in the normal growth pattern of the jaw. These patients have been shown to have increased vertical development of maxillary molars, increased lower anterior face height, steepened mandibular plane angle, obtuse gonial angle, and a palatal plane that is tipped down posteriorly when compared to non-affected individuals^{2,4,6,7}. As a result, these patients generally have a long lower face, decreased SNB angle, and less prominent pogonial projection, an appearance which historically has been referred to as a “long face” syndrome. Nielsen found that these individuals typically have a more posteriorly directed growth pattern of the mandibular condyle, which results in a mostly vertical vector of growth expressed at the chin⁵. Subtelny and Sakuda found that “in the average skeletal open bite there is supraeruption of the upper incisors and molars, while the mandibular incisors and molars were not found to be

infraerupted”². Frost and colleagues, comparing a sample of anterior open bite patients to normal controls, found that the “deformity existed below the palatal plane and involved the mandibular plane secondary to maxillary dentoalveolar vertical excess”⁸. Based on these findings, it can be concluded that the goal of orthodontic correction of skeletal open bite is to reposition the maxillary posterior dentition more superiorly, producing counterclockwise rotation of the mandible, decrease in anterior face, increased pogonial projection, and, ultimately, increase in the vertical overlap of the incisors.

Conventional Orthodontic Treatment

Once the etiology of a malocclusion has been established the objectives of orthodontic treatment can be evaluated. Since the primary morphological characteristics of anterior open bite are due to supraeruption of the posterior dentition, it is suggested that treatment should be directed at intruding the posterior maxilla^{9,10}. Due to the reciprocal nature of orthodontic mechanics, it is difficult to achieve posterior tooth intrusion without extrusion of the anterior teeth. Since the maxillary incisors are rarely undererupted in an anterior open bite, this possible side effect is not desirable, and this can result in not only an unaesthetic appearance to the smile but also a potentially unstable treatment result.

A wide variety of treatment techniques have been used over the years for the correction of vertical maxillary posterior excess resulting in anterior open bite. The various treatment approaches can typically be grouped into two general categories: 1) Prevention of the passive eruption (relative intrusion) of posterior teeth *during* growth, and 2) active intrusion of the posterior teeth *after* the adolescent growth spurt has completed. In the mixed dentition, high-pull headgear has traditionally been the treatment of choice for many

clinicians because it has been shown to successfully hold the vertical development of the dentition as well as the maxillary sutural growth⁶. Including an acrylic splint in conjunction with the headgear can create a single anchor unit that controls tipping of the maxillary molars. This has been shown to displace the maxilla superiorly and distally, with clockwise rotation of the palatal plan and relative intrusion of the maxillary molars¹¹. Functional appliances, such as the open bite bionator, have been used in the mixed dentition to help control the eruption of posterior teeth. A longitudinal study by Defraia and colleagues showed modest improvements in the overall vertical dimension, no significant change in the MPA, and no favorable effects on the extrusion of posterior teeth¹². Finally, vertical pull chin cups have been shown to effectively reduce the mandibular plane angle and produce less molar extrusion, but have not gained the same popularity as other treatment modalities. All of these appliances require extremely high patient compliance for a relatively lengthy period of time and acceptable results can be very difficult to achieve in a non-cooperative patient.

In post-adolescent patients, appliances containing bite-blocks with repelling magnets, such as the active vertical corrector (AVC), have been implemented as a means of intruding posterior teeth and allowing counterclockwise rotation of the mandible¹³. The AVC has been shown to intrude both maxillary and mandibular molars as well as allowing some extrusion and lingual tipping of anterior teeth. However, the appliance must be worn a minimum of 12 hours per day and due to the thickness of acrylic coverage of posterior teeth (requires 7 mm of interocclusal opening), can provide a significant challenge for most patients. An alternative technique known as the Multi-loop Edgewise Archwire has been advocated to intrude posterior teeth^{14,15}. This uses a multilooped .016 x .022 SS archwire in a .018 slot dimension with heavy anterior elastics. An evaluation of 55 patients treated with

the MEAW technique found that open bite correction was obtained by extruding maxillary and mandibular incisors and uprighting molars. As would be expected, this technique had little effect on the skeletal pattern on subjects categorized as non-growing¹⁵.

As with any orthodontic treatment, the stability of the final outcome is of utmost importance. It has been suggested that extrusion of teeth is an unstable tooth movement especially in the adult population¹⁶. Profitt states that “...*elongating the lower incisors to close a moderate anterior open bite is a quite stable procedure. Elongation the upper incisors is less stable, and this should be kept in mind when retention is planned*”¹.

However, no quantitative evidence has so far been provided to support this claim. It has been shown that early treatment of an open bite malocclusion can provide better results with a smaller degree of relapse, but this finding may be confounded by the fact that spontaneous correction of the open bite can occur during the natural development of the teeth and jaws¹⁷.

Janson et al. evaluated a sample of 21 adolescent open bite patients treated with fixed orthodontic appliances and vertical anterior elastics and found that 38.1 % had a clinically significant relapse of the open bite as defined by a negative overbite measurement after a mean of 5 years¹⁷. The primary factors that may have contributed to this relapse were shown to be the vertical development of the posterior mandibular teeth in conjunction with the smaller vertical development of the maxillary and mandibular incisors when compared to the control group. Few studies exist evaluating the stability of anterior open bite treatment during the permanent dentition, but a recent review of the literature found that approximately 80% of patients treated for an anterior open bite have been show to have positive overlap at the latest follow-up¹⁸. However, the aesthetic outcomes of the treatments are rarely, if ever, reported. Poor aesthetics may include an excessively gummy smile, increased lower face

height with subsequent lip incompetency, and deficient chin projection, all of which can produce an unaesthetic result.

Surgical-Orthodontic Treatment

As discussed, the most common etiologic factor in a skeletal anterior open bite is excessive vertical development of the posterior dentition. Historically, the way to achieve true intrusion of posterior teeth consistently has been through a combined orthodontic and surgical approach. The surgical correction of a vertical posterior maxillary excess typically involves a LeFort I osteotomy of the maxilla, with superior repositioning of the posterior maxilla subsequent to removal of bone from the lateral walls of the nose, sinus, and nasal septum. Superiorly repositioning the maxilla can be accomplished in one piece or in segments. The repositioning of the maxilla allows for mandibular autorotation, which shortens the anterior face height, increases the overbite, and improves the pogonial projection⁸. The maxillary osteotomy treatment has become a very popular choice for clinicians treating open bite patients and has been shown to have a good success and stability^{8,19-21}. Denison and colleagues, when examining 66 subjects treatment with a LeFort I osteotomy for the correction of an anterior open bite, evaluated the changes that occurred both during surgery and at one-year posttreatment and showed that 42.9% of subjects had a significant increase in facial height, eruption of maxillary molars, and a significant decrease in overbite²⁰. Only 6 patients (21.4%) had reopening of the anterior open bite beyond incisor overlap. The authors rationalized that the overbite was maintained despite the increase in facial height due to the compensatory eruption of the maxillary incisors²⁰. Similarly, Profitt et al. evaluated 28 patients undergoing a LeFort I osteotomy and found that in 75% of the

patients with a posttreatment increase in anterior face height, continued eruption of the incisors helped maintain the positive overbite¹⁹. More recently, Epseland reported that most of the skeletal relapse that occurs following surgery is during the first 6 months and always in the direction opposite of the surgical movement²¹.

An alternative option for the surgical correction of a skeletal open bite is through the counterclockwise rotation of the mandible following a bilateral sagittal split osteotomy. This treatment has traditionally been unpopular due to the questionable stability of the procedure. However, with the development of rigid fixation, some authors have reported good success. Joondeph and Bloomquist suggest several advantages to closing an anterior open bite with a mandibular procedure²². These include limiting the surgery to a single jaw and avoiding the potential adverse esthetic changes associated with maxillary LeFort impaction. In addition, the authors reference an unpublished article by Horwitz that evaluated 20 patients treated with a BSSO for open bite closure and found that 10% relapsed to the point where they had no incisor overlap²². However, as Joondeph noted, the study sample was small and the pretreatment open bites were relatively mild.

Regardless of the long-term stability of either of these surgical procedures, the complexity, risks, and morbidity associated with surgery together with the financial burden to the patient have encouraged a search for alternative clinical approaches to correct vertical posterior maxillary excess resulting in anterior open-bite.

Treatment of Open Bite with Skeletal Anchorage

Although the clinical application of temporary skeletal anchorage for orthodontic tooth movement has only recently been developed, the concept was envisioned as early as

1945. Gainsforth and Higley theorized that “if anchorage could be gained from a point within the basal bone, stability would be greatly increased”, and placed vitallium screws in a dog mandible for the retraction of canine teeth with minimal success²³. The first report in the literature of the clinical application of Temporary Skeletal Anchorage appeared in 1983 by Creekmore and Eklund, who placed a vitallium bone screw just below the anterior nasal spine to intrude maxillary incisors²⁴. In 1998, Melsen and colleagues presented several case reports involving a 0.012” stainless steel ligature wire placed through a hole cut through the infrazygomatic crest to provide absolute anchorage in patients with no maxillary posterior teeth²⁵. The first article to document the use of skeletal anchorage for posterior tooth intrusion was published by Umemori and Sugawara in 1999. This case report introduced their Skeletal Anchorage System (SAS), which involved titanium surgical miniplates placed in the posterior mandible to intrude the mandibular molars for open bite correction²⁶. Two cases were presented and lower molars were intruded 3.5 mm and 5.0 mm to close the anterior open bite with minimal incisor extrusion²⁶. Sherwood and colleagues later reported open bite correction as a result of maxillary molar intrusion²⁷. In this study, four adult patients had miniplates placed in the infrazygomatic crest with a mean molar intrusion of 1.99 mm (range, 1.45-3.32). In addition, the anterior facial heights were decreased as the mandibular rotated counterclockwise and B-Point rotated upward and forward²⁷. In the past five years, additional case reports have been published showing excellent results when skeletal anchorage was utilized for posterior tooth intrusion²⁸⁻³⁶. However, these reports are generally of small samples of patients and only two^{29,32} evaluated the patients in retention, with one showing reopening of the anterior open bite to the point that retreatment was indicated²⁹. The largest sample to date with follow-up data was reported by Sugawara and

colleagues in 2002. In this article, 9 patients were treated with the Skeletal Anchorage System discussed previously, and lateral cephalometric radiographs were taken one year post-debond. The mandibular first molars were intruded an average 1.8 mm with an average relapse of 0.5 mm or 27.2%³⁷. However, no study has been published showing the post-treatment changes following maxillary molar intrusion alone. Although suggestions have been made that the use of TSA may be a valid treatment alternative as compared to maxillary osteotomy, a current search of the literature found only one report that directly compared the treatment outcome of posterior tooth intrusion via TSA and surgical maxillary impaction³⁸. The study suggested that molar intrusion produced a comparable treatment result to orthognathic surgery. However, the orthognathic surgery in the comparison group involved both jaws and no follow-up data was provided to assess stability of the treatment results.

The use of temporary skeletal anchorage is a constantly evolving clinical technique that has the potential to facilitate the clinical treatment of difficult to manage malocclusions. In the past, many such malocclusions could only be treated sufficiently by a combined orthodontic and surgical approach. Data reporting the effectiveness and stability of significant intrusion of posterior teeth remains scarce. Although preliminary studies have shown promising treatment results, more work must be done to determine the predictability of an efficient and stable outcome. Treatment outcomes and stability using TSA have not yet been adequately evaluated in comparison to the traditional therapy of maxillary osteotomy. If temporary skeletal anchorage proves to be as effective and stable as maxillary osteotomy for posterior intrusion, with less morbidity, the clinical implications will be significant as both practitioners and patients have a less invasive and less cost restrictive treatment option.

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SECTION II

MANUSCRIPT

INTRODUCTION

The skeletal anterior open bite has long been considered one of the most difficult malocclusions to treat using traditional orthodontic mechanics. Various factors have been associated with the development of an anterior open bite ranging from vertical skeletal growth discrepancies, abnormal size and function of the tongue, and finger or thumb-sucking habits¹⁻⁵. When compared with non-affected individuals, patients with skeletal open bite have been shown to have a characteristic skeletal pattern including increased vertical development of maxillary molars, increased lower anterior face height, steepened mandibular plane angle, obtuse gonial angle, and a palatal plane that is tipped down posteriorly^{1,3,5,6}. As a result, these patients generally have a longer lower face and a retruded mandible with less prominent chin projection, an appearance which historically has been referred to as a “long face” syndrome. The predominate skeletal features of the anterior open bite usually occur secondarily to excessive vertical development of the maxillary posterior dentition suggesting that one goal of orthodontic correction of this malocclusion should be to reposition the maxillary posterior dentition more superiorly^{1,7}.

Due to the reciprocal nature of orthodontic force delivery it can be difficult to achieve molar intrusion without the extrusion of anterior teeth. Anterior tooth extrusion generally

will only mask the underlying skeletal deformity, potentially resulting in undesirable facial aesthetics as well as an unstable result. Intrusion of posterior teeth can be accomplished by a variety of treatment techniques including high-pull headgear with or without acrylic splints^{5,8}, functional appliances such as the open bite bionator⁹, active bite blocks with repelling magnets¹⁰, the multi-loop edgewise archwire^{11,12} and nickel-titanium archwires with anterior elastics¹³. However, each of these techniques requires a high level of patient compliance and often cannot produce true molar intrusion, particularly in the non-growing patient. As a result, surgical correction involving impaction of the posterior maxilla has become the generally accepted way to intrude maxillary molars, allowing the mandible to rotate forward and upward shortening the anterior face height, increasing the overbite, and improving the pogonial projection⁷. This has been shown to produce not only excellent aesthetic results, but also good stability long-term^{7,14-16}.

Recently, skeletal anchorage in the form of implants, miniplates, and miniscrews has been introduced to orthodontics to provide a source of absolute anchorage to aid in tooth movement. Umemori and colleagues were the first to document the use of skeletal anchorage for posterior tooth intrusion. Their case report introduced their Skeletal Anchorage System (SAS), which involved titanium surgical miniplates placed in the posterior mandible to intrude mandibular molars for open bite correction. Two cases were presented showing a significant amount of mandibular molar intrusion to close an anterior open bite with minimal incisor extrusion¹⁸. Subsequent case reports have shown successful molar intrusion with subsequent closure of the anterior open bite¹⁹⁻²⁸. However, these reports are generally based on small samples of patients, and only two^{21,24} evaluated the patients in retention, with one showing reopening of the anterior open bite to the point that retreatment

was indicated²¹. Only one study has reported the changes that occur at least one year following the completion of treatment²⁹. In this article, 9 patients were treated with the Skeletal Anchorage System described by Umemori and colleagues and lateral cephalometric radiographs were taken one year post-debond. The mandibular first molars were intruded an average 1.8 mm with an average relapse of 0.5 mm or 27.2%²⁹. To date, no study has been published showing the post-treatment changes following maxillary molar intrusion alone.

Suggestions have been made that the use of TSA may be a valid treatment alternative to maxillary osteotomy for the treatment of openbite. However, a current search of the literature found only one report that directly compared the treatment outcome of posterior tooth intrusion via TSA and surgical maxillary impaction³⁰. In that study, molar intrusion with temporary skeletal anchorage produced a comparable treatment change to orthognathic surgery involving both jaws but no follow-up data was provided to assess stability of the treatment results.

The primary goal of this research was to compare the treatment outcomes and stability, at least 6 months following posterior tooth intrusion for anterior open bite correction, of patients treated and TSA's and those treated with maxillary osteotomy. The two groups were frequency matched based on the sex and age frequencies in the TSA group.

MATERIALS AND METHODS

Sample Selection

Patients diagnosed with an anterior open bite (as defined by cephalometric overbite measurement less than 0 mm) who were treated either with temporary skeletal anchorage (TSA) to intrude posterior teeth or who underwent orthognathic surgery in conjunction with

orthodontic treatment were eligible for inclusion. Patients with anterior open bite related to a pathologic problem, recognized syndrome, or acute trauma were excluded. The study was approved by the Biomedical Institutional Review board. Sixteen patients treated at either the UNC Department of Orthodontics or a community-base private practice between April 2003 and October 2006 met these inclusion criteria. Seventy-six patients who had a LeFort I maxillary osteotomy only, stabilized with rigid fixation, were identified from the clinical records of the Dentofacial program at the UNC Memorial Hospital between November 1986 and July 2006.

Lateral cephalometric radiographs were required at three different time points; Pre-treatment/pre-surgery (T1), post-treatment/post-surgery (T2), and follow-up at least 6 months post-treatment/post-surgery(T3) (Table 1). Four of the TSA patients were excluded due to lack of records. No restrictions were placed on growth status of patient, type of TSA, or type of rigid fixation used. Twelve surgery patients were selected to match the age and gender frequency distributions in the TSA group.

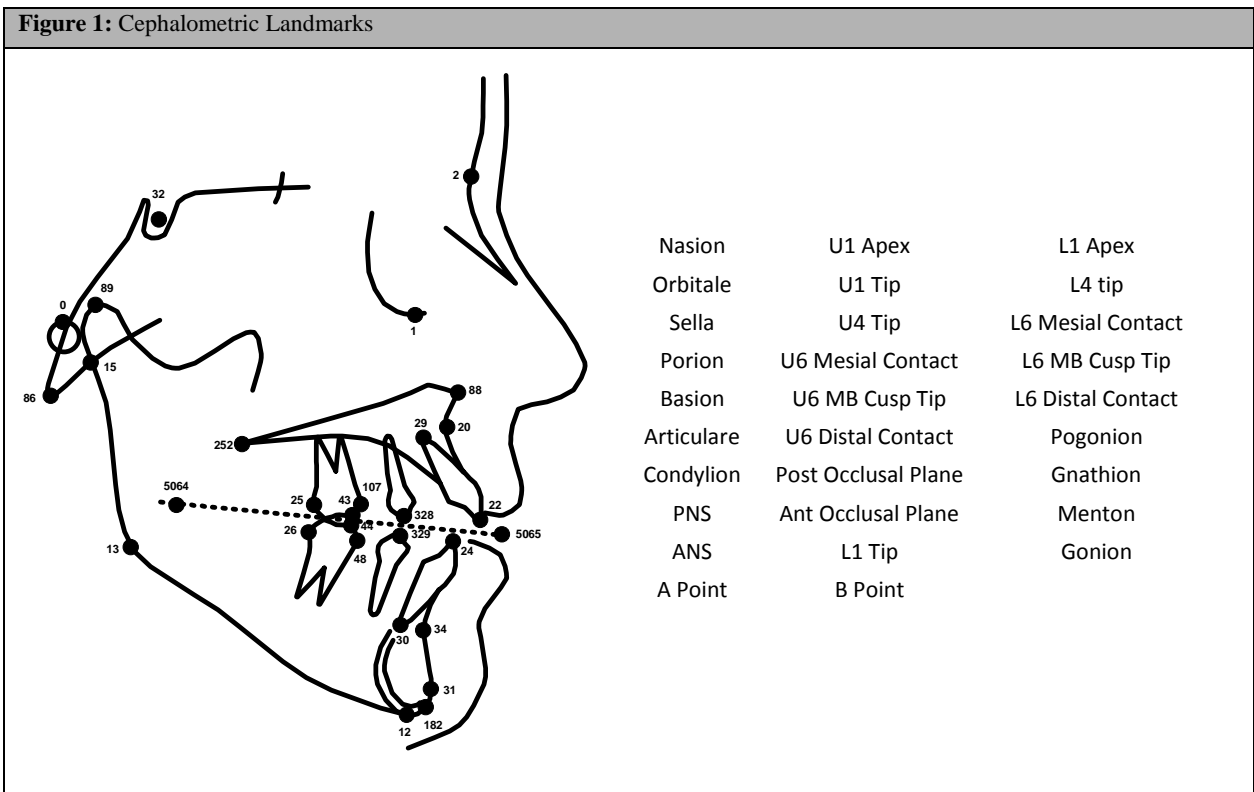
Table 1: Treatment Time points

	TSA group	Surgery Group
T1	Prior to posterior tooth intrusion	Prior to Surgery
T2	Removal of fixed appliances	6-8 weeks following Surgery
T3	At least 6 months after removal	At least 6 months after surgery

Cephalometric Analysis

Lateral cephalometric radiographs at both locations were taken at a standardized distance with a magnification of 8%. Cephalograms were imported into Dolphin Imaging

Software version 9.0 (Charsworth, CA). Digitization of all radiographs was performed by a single examiner (TH) using a 29-point model. Figure 1 summarizes these points and provides a visual representation of the digitization model. The reliability of the measurements was assessed by the intraclass correlation statistic with ten randomly selected cephalograms digitized on three separate occasions over a two week interval by the same examiner.



Changes during treatment (T1 to T2) and following the completion of treatment (T2 to T3) were calculated for each of the skeletal (Table 2) and dental (Table 3) measurements of interest separately for each group. . The skeletal measurements include anterior face height (Na-Me), mandibular plane angle (SN to Go-Gn), SNA, and SNB. The dental measurements include overbite, maxillary incisor tip to palatal plane (ANS-PNS), maxillary first molar mesial cusp tip to palatal plane, mandibular incisor tip to mandibular plane, and

mandibular first molar mesial cusp tip to mandibular plane. Because of the small sample size, only descriptive statistics are reported.

Table 2. Sample Demographics				
	Sample Size		Mean Age in Years (Range)	Mean Recall Period in Years (Range)
	Female	Male		
TSA Group	11	1	23.6 (13.3-45.4)	1.1 (0.5-3.1)
Surgery Group	11	1	23.9 (13.8-44.5)	2.1 (0.8-5.3)

TSA, Temporary Skeletal Anchorage

RESULTS

Twelve patients treated with temporary skeletal anchorage for posterior tooth intrusion met all inclusion criteria. The sample demographics are summarized in Table 2. Overall, the skeletal and dental measurements at T1 for both the TSA and Surgery group were remarkably similar (Table 3 and 4).

With regards to the skeletal measurements, greater treatment changes were seen in the patients treated with a maxillary osteotomy. The total anterior face height and mandibular plane was decreased a mean 3.3 mm and 2.1° more, respectively, in the surgery group and SNA was shown to increase 2.8 mm in the surgery group while the TSA group had a slight decrease. Despite the greater changes in face height and mandibular plane during treatment, more post-treatment relapse was noted in this measurement for the surgery group. All other skeletal measurements showed similar treatment and retention changes.

Overall, the dental measurements were also very similar for the two treatment groups at the T1 cephalogram. The pretreatment openbite was 2.1 mm greater, on average, in the surgery group, but the average overbites at the completion of treatment were nearly identical in both groups. The amount of molar intrusion in the TSA group was evaluated in relation to

the palatal plane and was shown to be a mean 1.2 mm. Molar intrusion for patients undergoing maxillary osteotomy was not measured since the osteotomy procedure disrupts palatal plane and therefore produces measurements that are of no value. Greater average vertical changes in the maxillary incisors and the mandibular incisors and molars occurred in the TSA group. The distance between U1-Palatal Plane and L1-Mandibular Plane increased a mean 0.8 mm more and the distance between L6-Mandibular Plane increased a mean 0.7 more in the TSA group. However, all dental measurements showed comparably small changes during the follow-up time period.

Table 3. Skeletal Measurements

<i>Measurements</i>	<i>T1(SD)</i>	<i>T2(SD)</i>	<i>T2-T1(SD)</i>	<i>T3 (SD)</i>	<i>T3-T2 (SD)</i>
Na-Me					
<i>TSA</i>	121.4 (9.9)	120.9 (9.5)	-0.5 (2.4)	121.0 (9.8)	0.1 (1.1)
<i>Surgery</i>	122.3 (5.9)	118.5 (7.5)	-3.8 (2.4)	119.5 (6.3)	1.0 (1.9)
SN to Go-Gn					
<i>TSA</i>	37.2 (4.2)	37.5 (4.6)	0.3 (1.4)	37.5 (5.0)	0.0 (1.3)
<i>Surgery</i>	38.0 (6.3)	35.6 (6.2)	-2.4 (2.1)	36.4 (6.6)	0.8 (2.1)
SNA					
<i>TSA</i>	79.5 (2.9)	79.1 (3.0)	-0.4 (1.2)	79.1 (2.9)	0.0 (1.0)
<i>Surgery</i>	79.1 (5.2)	81.9 (6.4)	2.8 (2.8)	81.2 (6.3)	-0.7 (1.1)
SNB					
<i>TSA</i>	76.5 (4.1)	76.1 (4.4)	-0.4 (0.9)	76.3 (4.3)	0.2 (0.6)
<i>Surgery</i>	76.5 (4.8)	78.1 (5.0)	1.6 (1.5)	77.4 (5.0)	-0.7 (1.3)

T1, Pretreatment; *T2*, Posttreatment; *T2-T1*, Treatment changes; *T3*, Follow-up; *T3-T2*, Post-treatment changes

Table 4. Dental Measurements

<i>Measurements</i>	<i>T1(SD)</i>	<i>T2(SD)</i>	<i>T2-T1(SD)</i>	<i>T3 (SD)</i>	<i>T3-T2 (SD)</i>
Overbite					
<i>TSA</i>	-1.0 (0.9)	1.7 (0.6)	2.7 (1.0)	1.8 (1.1)	0.1 (0.9)
<i>Surgery</i>	-3.1 (2.1)	1.6 (0.9)	4.7 (2.4)	1.5 (0.8)	-0.1 (1.1)
U1 to ANS-PNS					
<i>TSA</i>	29.5 (3.4)	30.4 (2.9)	0.9 (1.3)	30.6 (3.1)	0.2 (0.6)
<i>Surgery</i>	29.4 (3.3)	29.5 (3.2)	0.1 (0.8)	29.7 (2.6)	0.2 (1.0)
U6 to ANS-PNS					
<i>TSA</i>	24.7 (2.8)	23.5 (2.8)	-1.2 (1.2)	23.7 (3.0)	0.2 (0.5)
<i>Surgery</i>	—	—	—	—	—
L1 to Go-Gn					
<i>TSA</i>	28.6 (3.2)	29.6 (3.2)	1.0 (0.8)	29.6 (3.4)	0.0 (0.9)
<i>Surgery</i>	29.9 (2.1)	30.1 (2.0)	0.2 (0.7)	30.4 (2.0)	0.3 (0.9)
L6 to Go-Gn					
<i>TSA</i>	36.2 (3.8)	37.3 (3.8)	1.1 (0.8)	37.5 (3.5)	0.2 (0.83)
<i>Surgery</i>	36.6 (3.1)	37.0 (2.9)	0.4 (0.8)	37.6 (2.9)	0.6 (0.6)

T1, Pretreatment; *T2*, Posttreatment; *T2-T1*, Treatment changes; *T3*, Follow-up; *T3-T2*, Post-treatment changes

Figures 2 and 3 illustrate the overbite for each of the twelve TSA and surgery patients at T1, T2, and T3. All patients had a negative overbite at the beginning of treatment, while a positive overbite was achieved during treatment and maintained for all but one of the surgery patients in the follow-up period. Figure 4 shows the relationship of the maxillary molar to the palatal plane for the TSA group only. All T1 measurements are adjusted to a value of zero and changes are visualized in relation to this measurement. Intrusion of the maxillary molar was achieved in 9 (75%) patients and 6 (50%) patients showed essentially no change in molar position following treatment. Figures 5, 6, and 7 show the relationships between maxillary incisor to palatal plane, mandibular molar to mandibular plane, and mandibular incisor to mandibular plane respectively in the individual TSA patients. A majority of patients had some degree of extrusion/eruption of the incisors and mandibular molars during treatment.

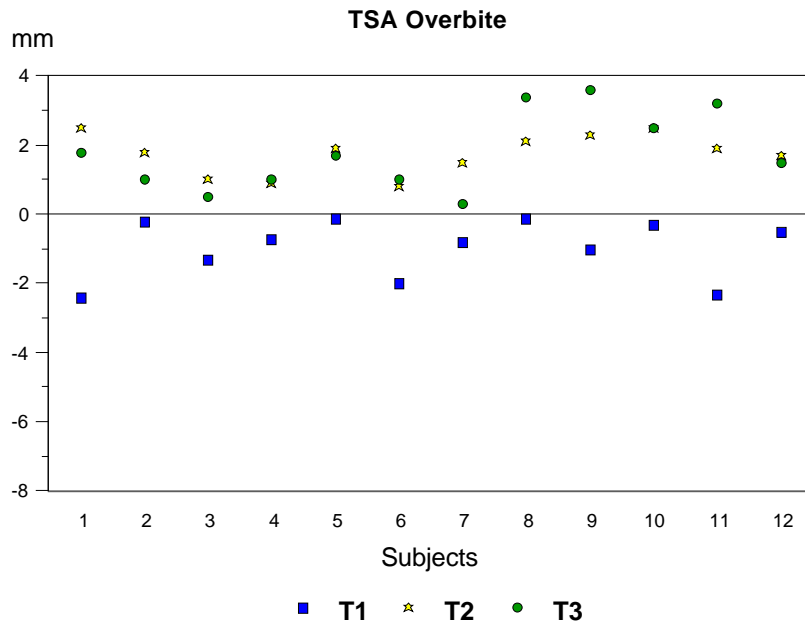


Figure 2: Overbite measurement for individual TSA patients at T1, T2, and T3. Patients are ordered by age from youngest(1) to oldest(12).

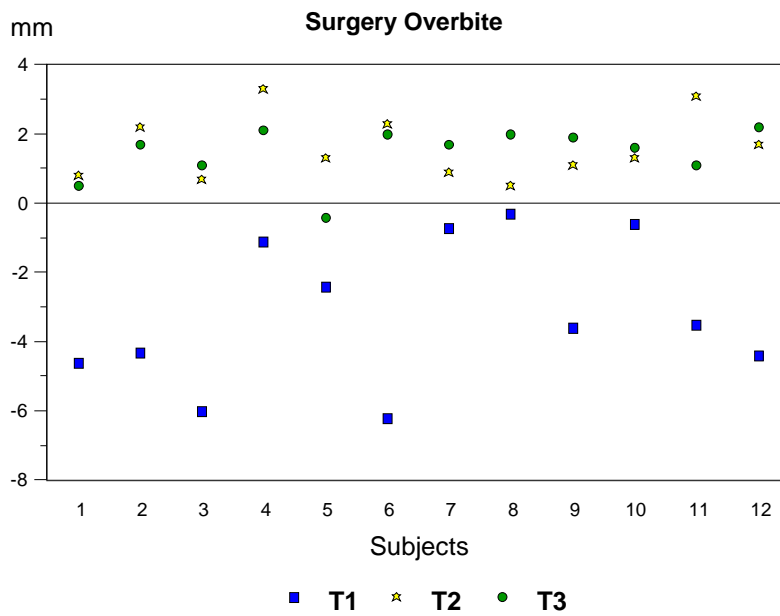


Figure 3: Overbite measurement for individual Surgery patients at T1, T2, and T3. Patients are ordered by age from youngest(1) to oldest(12).

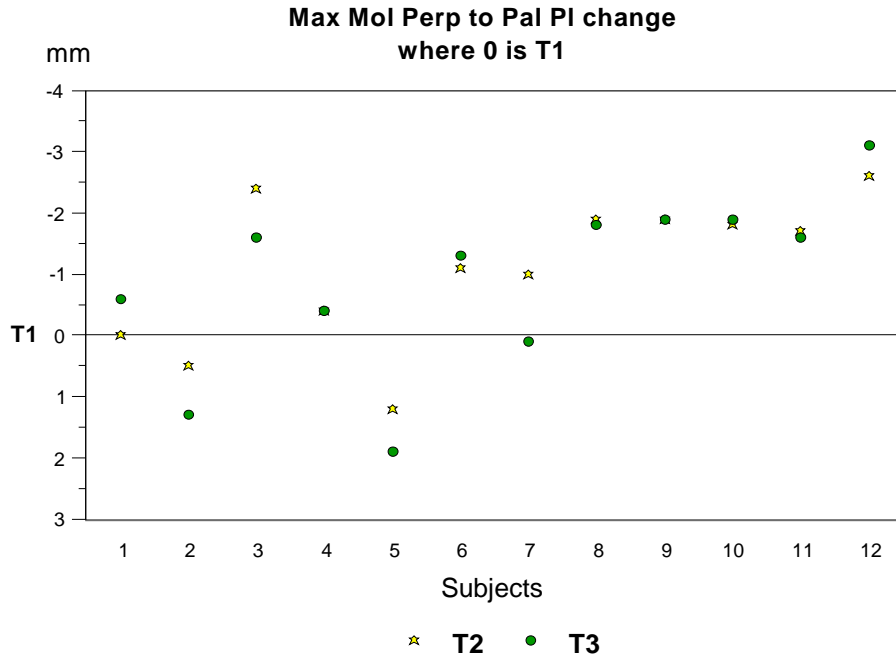


Figure 4: Vertical maxillary molar position relative to palatal plane. T1 values are adjusted to a value of 0. Negative changes represent molar intrusion and positive changes represent extrusion/eruption. Patients are ordered by age from youngest (1) to oldest (12)

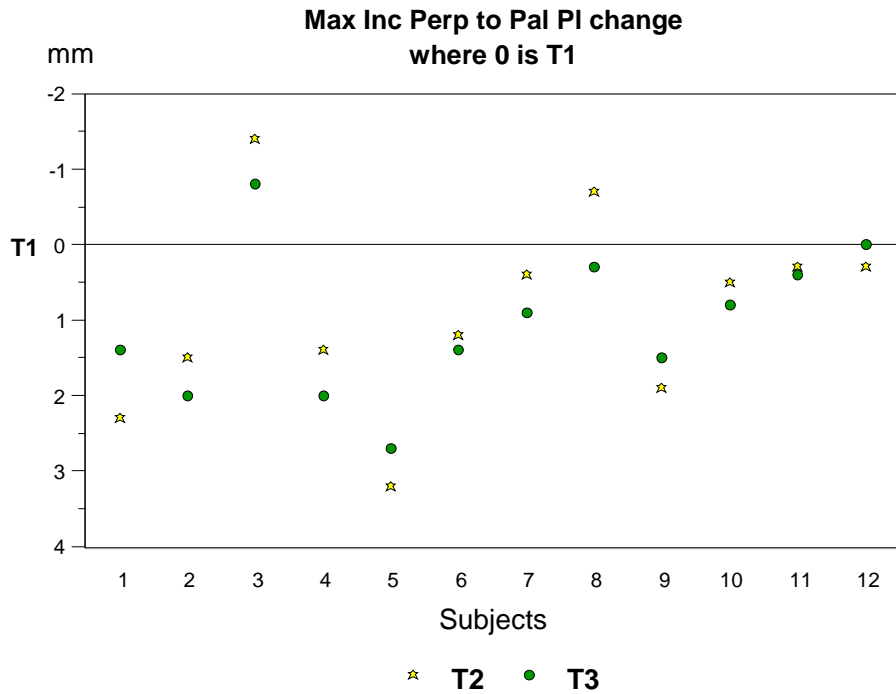


Figure 5: Vertical maxillary incisor position relative to palatal plane. T1 values are adjusted to a value of 0. Negative changes represent incisor intrusion and positive changes represent extrusion/eruption. Patients are ordered by age from youngest (1) to oldest (12).

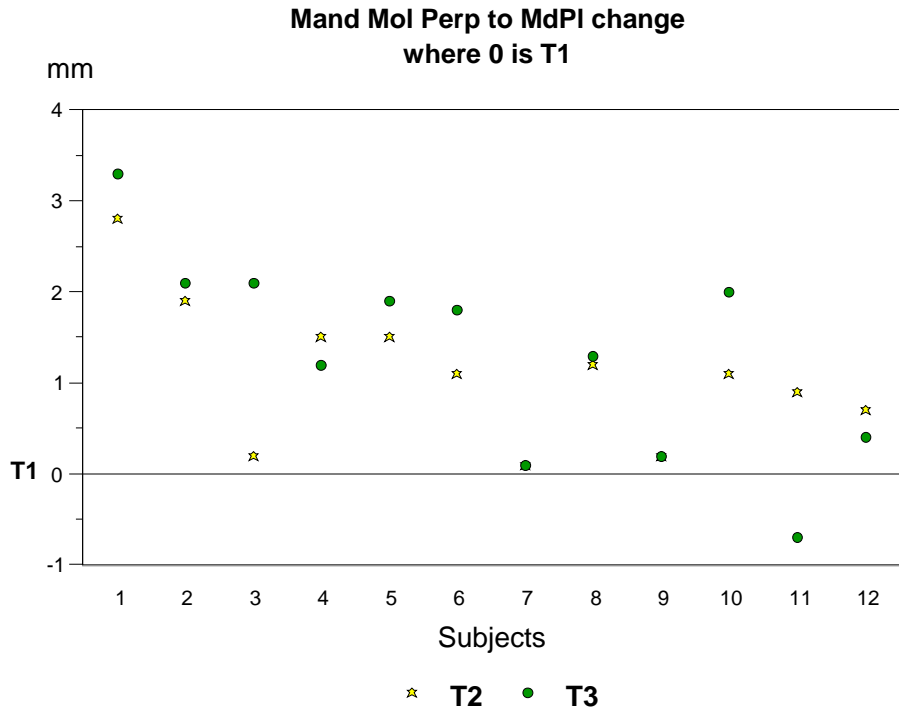


Figure 6: Vertical mandibular molar position relative to mandibular plane. T1 values are adjusted to a value of 0. Negative changes represent molar intrusion and positive changes represent extrusion/eruption. Patients are ordered by age from youngest (1) to oldest (12).

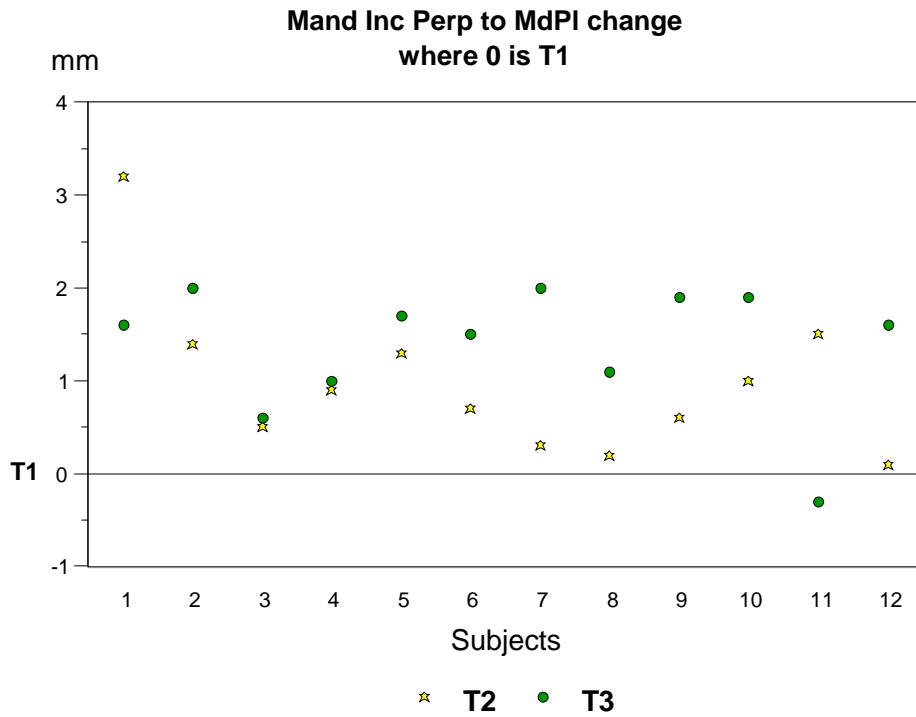


Figure 7: Vertical mandibular incisor position relative to mandibular plane. T1 values are adjusted to a value of 0. Negative changes represent incisor intrusion and positive changes represent extrusion/eruption. Patients are ordered by age from youngest (1) to oldest (12).

DISCUSSION

The results of this study show that skeletal anchorage can be an effective and stable technique for the correction of skeletal anterior open bites. Although only twelve patients were evaluated, this is the largest sample with the longest follow-up available to date. All patients achieved a positive overbite at the completion of treatment with minimal relapse noted during the post-treatment follow up (up to 3 years). No patient in the TSA group had a negative overbite reoccur during the retention time period. Skeletal and dental characteristics between the TSA and Surgery group were comparable prior to the initiation of treatment. While the surgery sample showed more profound changes in skeletal measurements post-treatment, both treatments achieved similar positive overbites with little to no changes in the follow-up time period.

Differences were noted between the groups in the amount of incisor and mandibular molar movement during treatment. In the TSA group, both the incisors and mandibular molars appear to have extruded an average of 1.0 mm during treatment while minimal changes were seen in the surgical group. This may explain why a smaller degree of skeletal change was seen in the TSA group than what would have been expected. Many of the patients included in this study were actively growing at the time of treatment, making it difficult to differentiate tooth extrusion from eruption that can occur in conjunction with the vertical growth of the maxillary and mandibular complex. By frequency matching the two samples by age and sex, the changes resulting from growth ideally would have occurred in both groups, but the pre-existing protocol for obtaining records for the orthognathic surgery patients may have affected the length of time between the pre and post-surgery timepoints.

As described previously, the T2 time point for the surgery group occurred 6-8 weeks following surgery, which, in some cases, allowed for only 2-3 months to elapse between the pre and post-surgery radiographs. In addition, since in most cases the T1 radiograph was taken immediately prior to surgery, any tooth movement that occurred prior to this cannot be evaluated. For the TSA group, the T1 radiographs were taken prior to initiating tooth intrusion while the T2 radiographs were taken at removal of fixed appliances, allowing for as many as three years to elapse between time points. This allows not only for a significantly longer amount of time for vertical growth to occur, but also may conceal the amount of extrusion that could occur in preparation for the surgical procedure. However, the differences may also be due simply to inadequate control of the vertical dimension in the TSA patients, in particular the mandibular molars, during treatment and should be taken into consideration in future cases.

To date, only one case study has evaluated the stability of open bite correction with skeletal anchorage on multiple patients. Sugawara and colleagues showed that the mandibular first and second molars were intruded an average 1.7mm and 2.8mm with a relapse rate of 27.2 % and 30.3 % respectively²⁹. However, these measurements were taken in reference to a functional occlusal plane defined at the T1 timepoint. Sugawara also provided measurements in relation to skeletal reference points such as mandibular and palatal plane, and when analyzing the mandibular molar intrusion to mandibular plane, as was done in this study, the relapse rate can be calculated as 16.7%. When applying this concept to the amount of maxillary molar intrusion in this sample, the same relapse rate of 16.7% is calculated. In addition, it is important to note that Sugawara's sample also showed a smaller amount of skeletal changes following treatment than would have been expected. This was

attributed to the extrusion of maxillary molars due to poor vertical control during treatment and resulted in the authors considering the placement of skeletal anchorage in both the maxillary and mandibular arches²⁹.

Kuroda and colleagues recently published a study directly comparing patients treated with skeletal anchorage to those treated with orthognathic surgery³⁰. In this article, 10 female patients treated with skeletal anchorage for posterior tooth intrusion were compared to 13 patients (4 male, 9 female) treated with orthognathic surgery involving both the maxilla and mandible. The authors found that the treatment outcomes in the patients treated with skeletal anchorage were equivalent to those who underwent surgical treatment. No follow-up data was presented to assess the stability of the results, but the authors claimed that the patients who had molar intrusion with skeletal anchorage “had excellent retention and stability in occlusion and facial appearance more than 2 year later”³⁰. In addition, significant skeletal changes were noted in the skeletal anchorage group with a decrease in both mandibular plane angle and total anterior face height of 3.3° and 4.0mm respectively³⁰. However, the patients in this study were treated with skeletal anchors placed in both arches which allowed for the intrusion of both the maxillary and mandibular molars. Since the eruption of the opposing molar was seen not only in this study but also by Sugawara and colleagues, both of which attempted to intrude teeth in only one arch, it may be concluded that better vertical control can be obtained if skeletal anchorage is applied in both arches.

This study provides insight into the long-term stability of tooth intrusion using skeletal anchorage, but much more work must be done before the orthodontic community can be more confident in the treatment results. A much larger sample of patients who are followed over many years will be required to ultimately reach this goal. One of the primary

shortcomings of this study is the inclusion of patients who likely were continuing to experience vertical facial growth. However, this sample simply represents the patients who have been and currently are being treated at the University of North Carolina Department of Orthodontics. Only when vertical dentoalveolar development has ceased will one be able to differentiate treatment results and potential relapse occurring as a result of the orthodontic mechanics from those due to growth. The other significant shortcoming in this study was that no specific protocol was followed for the treatment of these patients. Treatment was provided by several different clinical faculty members at UNC, many of whom were, at the time, inexperienced in the use of skeletal anchorage, using a wide variety of appliance designs and techniques. Despite these limitations, the outcomes of this study appear promising, showing that the overbite can be corrected by intruding maxillary molars and can be maintained, at least in the short-term, following the removal of orthodontic appliances.

CONCLUSION

1. True molar intrusion resulting in openbite correction can be obtained using temporary skeletal anchorage.
2. Overbite present at the end of treatment was shown to be relatively stable for as long as three years following treatment
3. Stability of the results are comparable to those found in patients undergoing orthognathic surgery
4. More emphasis should be placed on the vertical control of incisors and mandibular molars in future treatment

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