SUCCESS RATES OF TEMPORARY ANCHORAGE DEVICES PLACED IN AN
ORTHODONTIC CLINIC

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ORTHODONTICS

ABSTRACT

In recent years, the use of a variety of temporary placed implants to attain absolute anchorage has been described in the orthodontic literature. The use of temporary implants, fixed to bone, overcomes some of the limitations of traditional anchorage and their reliance on patient compliance. The purpose of this study was to evaluate factors relating to the successful placement of miniscrew temporary anchorage devices in an orthodontic clinic. The orthodontic records of patients who had miniscrews placed during their treatment at the University of Alabama at Birmingham School of Dentistry Postgraduate Orthodontic Clinic were selected. After application of the inclusion and exclusion criteria, the final study sample consisted of 32 patients who received a total of 58 miniscrew anchorage devices. The records of all 32 patients were analyzed to determine implant site, time before implant loading, experience level of clinician placing the implant, and whether the implant remained stable during the loading period. In addition, a vitality test was performed on each patient to determine the vitality of all the teeth in the quadrant where the miniscrew was placed. The overall success rate was 75.8%. Miniscrews placed in the maxilla were clinically more successful than those placed in the mandible. There was no statistically significant difference in time before miniscrew loading, patient age, and experience level of clinician. Following adjustment for multiple implant failures and successes in individual patients, experience level of the clinician placing the miniscrew became statistically significant. The experienced
clinician had a greater expectation of success then the novice group. In addition, 100% of the teeth tested as vital. These results indicate that the placement of miniscrews can be accomplished successfully in an orthodontic clinic. This study also suggests that there is a learning curve to the placement of miniscrews and orthodontic clinicians can expect their success rates to increase as they place more miniscrews.
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TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LITERATURE REVIEW</td>
<td>1</td>
</tr>
<tr>
<td>History</td>
<td>1</td>
</tr>
<tr>
<td>Orthodontic Anchorange</td>
<td>1</td>
</tr>
<tr>
<td>Dental Implants</td>
<td>2</td>
</tr>
<tr>
<td>Temporary Anchorage Devices</td>
<td>3</td>
</tr>
<tr>
<td>Classification</td>
<td>7</td>
</tr>
<tr>
<td>Biology of Bone and Miniscrew Implants</td>
<td>9</td>
</tr>
<tr>
<td>Treatment Planning</td>
<td>12</td>
</tr>
<tr>
<td>Miniscrew Applications</td>
<td>14</td>
</tr>
<tr>
<td>Complications</td>
<td>21</td>
</tr>
<tr>
<td>Miniscrew Success Rates and Factors</td>
<td>25</td>
</tr>
<tr>
<td>SUCCESS RATES OF TEMPORARY ANCHORAGE DEVICES PLACED IN AN ORTHODONTIC CLINIC</td>
<td>29</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>45</td>
</tr>
<tr>
<td>GENERAL LIST OF REFERENCES</td>
<td>46</td>
</tr>
<tr>
<td>APPENDIX</td>
<td></td>
</tr>
<tr>
<td>A INSTITUTIONAL REVIEW BOARD FOR HUMAN USE APPROVAL FORM</td>
<td>51</td>
</tr>
</tbody>
</table>
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sample characteristics</td>
</tr>
<tr>
<td>2</td>
<td>Regression models using GEE to account for clustering among patients</td>
</tr>
</tbody>
</table>
LITERATURE REVIEW

In 1687 Sir Isaac Newton compiled the basis for classical mechanics with his three laws of motion. His third law states that for every action there is an equal and opposite reaction. This statement has proven to be of utmost relevance to orthodontic treatment and more specifically to orthodontic anchorage. Orthodontic anchorage is defined as the resistance to unwanted tooth movement. Orthodontists attempt to move specific teeth while preventing the reciprocal effects of forces on other teeth. Traditionally, the control of unwanted tooth movement has been attempted with a variety of extra and intraoral devices. These appliances are often uncomfortable, awkward, and unaesthetic. As result, patient compliance is often less than ideal which can compromise treatment outcomes. In recent years, the orthodontic literature has described the use of a variety of temporary placed implants to attain absolute anchorage. The use of temporary implants, fixed to bone, overcomes the limitations of traditional anchorage and their reliance on patient compliance.

History

Orthodontic Anchorage

The concept of moving teeth relative to one another can be traced back to the 1700’s. In 1723, Pierre Fauchard described the fabrication of an ideally shaped metal plate and the ligation of teeth to it in order to change the location of the teeth. This appliance is now known as the expansion arch. In 1822, Gunnell described the use of
occipital anchorage via head gear to correct protrusion of the mandible. He recognized the inherent difficulty in using teeth for anchorage and instead opted to use the immobile occipital bone. Delabarre made a wire crib that ligated teeth to one another and proved excellent as anchorage. This crib was later modified by Schange who attached it to a palatal plate as anchorage and then moved teeth relative to the palatal plate with silk ligatures. In 1843, Desirabode is credited with recognizing differential movement of teeth relative to the lengths of their roots. He used teeth with longer roots as anchorage to move smaller teeth. Edward Angle introduced the concept of stationary anchorage in 1887. He recognized that the retraction of a cuspid into a bicuspid extraction space would cause the molars to move mesial resulting in anchorage loss. Angle therefore combined an expansion arch, attached the posterior teeth, with a cuspid traction screw that created a posterior anchor unit to retract the single cuspid. Angle went on to advocate the use of a headgear to the molars to hold them as stationary anchors in the retraction of cuspids.

Dental Implants

The first record of replacing missing teeth with an implantable device can be found in a patent submitted in 1909 by EJ Greenfield. Greenfield proposed the placement of a metal framed cage into a hole drilled directly into the alveolus. Greenfield theorized that bone would grow into the cage and hold a crown cemented to the frame. In the 1940s, Alvin Strock, critiqued Greenfield’s design and concluded that the iridioplatinum cage was not strong enough to withstand masticatory forces. Strock abandoned the cage design and opted to use Vitallium fixation screws designed by
Venable and Stuck. He used 5/8-inch Vitallium Venable screws to replace lost incisors. Strock discussed two points of implantation that hold true today. He suggested that immediate placement and loading of an implant is possible if the bone is of good quantity and quality and the implant is stable upon placement. He also directed attention to occlusion and advised that occlusal trauma could lead to implant failure. In the 1950s Per Ingvar Branemark noted bone growth into titanium chambers he was using to study blood circulation in bone marrow. This discovery led to the experimentation and subsequent description of osseointegration. Branemark was the first to advocate a 4-6 month healing time before loading to allow for complete osseointegration. Earlier loading, according to Branemark, allowed for micromotion of the implant and permitted fibrous tissue to grow between the implant and bone, inhibiting osseointegration.

Temporary Anchorage Devices

The concept of implantable temporary anchorage devices (TADs) to attain basal bone anchorage was first described by Gainsforth and Higley in 1945. They inserted a 3.4 mm diameter by 13 mm long vitallium screw into the ascending ramus of six dogs. The screws were immediately loaded with 140 to 200g of force and used to retract cuspids. All the screws failed within the first month. This may have been due to either dynamic loading of the implants or peri-implant infection since antibiotics were not administered to the dogs. In 1983, Creekmore and Eklund published the first clinical report of the use of a TAD in a patient. They placed a vitallium screw into the anterior nasal spine and used it to correct a deep overbite by intruding the maxillary incisors. The TAD was loaded ten days after placement and was deemed a success.
In the years following the work of Creekmore and Eklund, orthodontists began publishing numerous case reports and studies introducing various TAD designs and systems. Miniscrews, miniplates, retromolar implants, palatal implants, fixation wire implants and palatal onplants are some of the implant systems described and being used in clinical orthodontics.

In 1983, Roberts and colleagues placed an intraosseous screw in the retromolar region to protract a second and third molar into an edentulous first molar space. They utilized a two stage system in which a 3.85 mm commercially pure titanium implant was placed and left to osseointegrate for nine months. The implant was then uncovered and a transmucosal post placed for attachment. Roberts attached the post to a patient’s lower left second bicuspid via an auxiliary wire to stabilize the premolar while the second and third molars were protracted a total of twelve millimeters. Longitudinal cephalometric analysis showed that the implant remained stationary for the three years it was loaded. Histomorphometric analysis following implant removal showed that 80% of the implant had direct osseous contact, confirming that the implant had osseointegrated.

Miniplate implants were first introduced in 1985 when Jenner and Fitzpatrick used a bone plate screwed into the ascending ramus to distalize a lower first molar. Miniplates have since been popularized by Sugawara who developed the Skeletal Anchorage System (SAS) in 1992. The SAS consists of a miniature titanium bone plate that is screwed into buccal cortical bone apical to the dentition. In Sugawara’s preliminary study using the SAS, he treated a patient who had declined orthognathic surgery but had a skeletal open bite. The treatment plan was to intrude the patient’s lower first and second molars in order to close the bite. A mucoperiosteal flap was
elevated and the miniplates were fixed to cortical bone with surgical bone screws. An arm from each plate extended through the sutured flap into the oral cavity for the attachment of elastics. The mandibular molars were intruded 3-5 mm over a period of five months and the overbite was effectively increased.

One of the main limitations of using implants for orthodontic anchorage is that they require adequate bone. In 1989, Block and Hoffmann\textsuperscript{12} presented a system of placing implant anchors onto the palate. They designed a thin titanium alloy disk, coated with hydroxyapatite that could be placed subperiosteally against bone for osseointegration. This onplant, as it was called, had a threaded hole in its center to which abutments could be placed and subsequently used as absolute anchorage.

To test their Onplant system, Block and Hoffmann\textsuperscript{12} conducted two studies. In the first study, the onplants were placed subperiosteally against the palates of dogs and allowed to osseointegrate. The onplants were then attached to the first premolars with springs and loaded with eleven ounces of force. Tooth movement toward the onplant was measured. The premolars moved 4-8 mm towards the onplant and the onplant remained stationary, indicating its ability to withstand orthodontic forces. In the second study, the onplants were placed on the palates of monkeys and used to determine if they could be used to stabilize molars during retraction of anterior teeth. A cast transpalatal bar fixed to the onplant, joined the first molar on one side to the second molar on the other side. Premolars were extracted bilaterally and the canines were retracted. The molars anchored to the onplant moved 1.2 mm forward, whereas the nonanchored molars moved forward 4.1 mm. The study concluded that the onplant provided sufficient anchorage to prevent significant mesial molar migration during the retraction of anterior teeth.
Straumann\textsuperscript{13} devised a screw type endosseous implant that could be placed in the palate. In 1996 Wehrbein and colleagues\textsuperscript{14} described the Straumann Orthosystem. The surface of the self-tapping Orthosystem implant was sand-blasted and acid etched to increase osseointegration. It had a diameter of 3.3 mm and was available in two lengths, 4.0 mm and 6.0 mm. Straumann recommended using lateral cephalometric films to determine the placement site and length of implant. Placement protocol required the palatal mucosa to be reflected, and pilot holes drilled. The implants were then screwed into the palatal bone and allowed to heal for 10-12 weeks. An abutment was then attached to the osseointegrated implant and orthodontic forces applied. After orthodontic movements are completed, a second surgical procedure is required to trephine out the osseointegrated implant.

In 1998 Melsen and colleagues\textsuperscript{15} introduced the zygomatic ligature as an alternative to implants and plates for achieving absolute anchorage. The zygomatic ligature is described a cheap and simple method for intruding and retracting maxillary incisors. A surgical procedure is needed for the placement of the wire. An incision is made to expose the infrapygomatic crest of the maxilla and two holes are drilled into the crest. A double twisted .012” soft stainless steel wire is looped through the two holes and left exposed in the oral cavity as the surgical flap is sutured closed. A spring is then used to connect the zygomatic wire to the anterior segment needing retraction. The wire, looped through bone, should provide absolute anchorage while the anterior teeth are retracted. This placement procedure proved to be successful in their case report. The wire was immediately loaded and used for 3-6 months. The wire provided adequate anchorage to retract the anterior segment, even though it eventually pulled through the
zygomatic bone. The authors acknowledged this result and expected it to occur. Their hope was that the desired tooth movement could be accomplished before the wire had time to travel completely through the zygoma.

In 1997, Kanomi\textsuperscript{16} introduced a miniature implant specific for orthodontic anchorage. Kanomi’s mini-implant was only 1.2 mm in diameter and was said to be placeable in almost any intraoral location. The protocol for placement of this mini-implant called for a full mucoperiosteal flap under local anesthesia. A pilot hole was drilled and the implant screwed in. The implant was allowed to osseointegrate before it was surgically uncovered with a mucosal punch. The implants placed in this study were stable for the four months they were loaded and they successful intruded mandibular incisors 6 mm over that time.

Following Kanomi, Costa and colleagues\textsuperscript{17} introduced a similar mini-implant screw that called for a much simpler placement protocol. In their case report, they placed 16 screws into 14 patients. The titanium screws had a diameter of 2 mm and were 9 mm in length. Their placement procedure did not require a mucoperiosteal flap. Instead the authors used a 1.5 mm pilot drill to perforate the cortical plate and then using a screwdriver, they screwed the screws in by hand directly through the mucosa. The screws were placed in both the maxilla and mandible and were loaded immediately. The study was a preliminary report that illustrated the successful use of mini-implants in a variety of locations.

Classification

In an effort to categorize the multitude of currently available TADs, Cope\textsuperscript{18} suggests that there are two main classes of implants, biologic and biocompatible. Each of
these classes can be further subdivided by the manner in which the TADs are attached to bone, either biochemical (osseointegrated) or mechanical.

Biologic TADs involve ankylosed or dilacerated tooth roots. An ankylosed root, when used for anchorage, is a biological TAD that is fixed to bone biochemically. A tooth with a dilacerated root is a biological TAD that is fixed to bone mechanically.¹⁸

Biocompatible TADs are usually a modified dental implant or surgical fixation method. When the TAD is a type an osseointegrated dental implant it is considered biochemical. If the TAD is a surgical fixation variant, it is considered a mechanical TAD, because it does not require osseointegration for stability.¹⁸

Cope¹⁸ went on further to clarify the terminology being used in the literature to describe TADs. For example, TADs have been referred to as microimplant, microscrew implant, mini-implant, mini dental implant, miniscrew, and screw-type implant. To differentiate between the words mini and micro, Cope used the dictionary. Mini refers to something small in relation to others of similar kind. Micro is short for microscopic, which infers that it requires magnification to be seen. Mini is more appropriate for orthodontic purposes because if the TADs were microscopic, orthodontists would have difficulty using them. Furthermore, Cope discusses the terms screw and implant. Screw refers to the shape or configuration of the TAD whereas the term implant refers to the intent of leaving an object in place for an extended period of time. Cope therefore recommends the term miniscrew implant (MSI).
Titanium endosseous implants have been successfully used to replace missing teeth for a number of years. In an attempt to evaluate the success of various implant systems, Smith\textsuperscript{19} established criteria to determine the clinical success of endosseous dental implants. The proposed threshold for success requires that 85\% of the implants be in use at the end of five years, and 80\% at the end of ten years. Adell, et al\textsuperscript{20} and Branemark and Albrektsson\textsuperscript{19} reported on success rates for the Branemark osseointegrated titanium implant. Adell evaluated the outcome of 734 consecutively placed maxillary implants and found an 84\% success rate in a 5 to 12 year post placement period. For mandibular implants he found a success rate of 93\% after ten years. Branemark and Albrektsson evaluated all of the mandibular implants placed during one year and found a 96.5\% success rate after five years. Cox and Zarb\textsuperscript{21} found ten year success rates to be 93\% for mandibular symphyseal implants and 82\% for the maxilla. These studies all concur that osseointegrated implants are highly successful.

The suitability of endosseous implants for use depends on osseointegration of the implant with the host bone.\textsuperscript{19} Without this feature, the implant would be considered a failure. In contrast, orthodontic miniscrew implants do not require osseointegration for clinical use, instead they rely on mechanical retention.\textsuperscript{18} In fact, osseointegration is discouraged by making the miniscrew surface smooth and polished. Though endosseous implants and miniscrew implants differ in their need for osseointegration, they do share many of the same bone adaptation responses upon insertion.\textsuperscript{22}

When an implant or miniscrew is surgically placed into vital bone, the bone healing events that follow are similar to those seen following a bone fracture. Immediately following insertion, a bridging callus forms composed of woven bone. The
initial woven bone has little load bearing capacity and serves as a framework for lamellar bone to form. As organized lamellae form, the callus is reduced in size, and the bone matures and gains strength. Under ideal surgical conditions and optimal surgical technique, only about 1 mm of bone dies around the circumference of the implant. This dead bone provides further structural support for the initial callus during the healing phase and is replaced with vital bone via remodeling.23

Bone adapts to its environment via modeling and remodeling. Modeling and remodeling are two distinct physiologic processes under different control mechanisms and are often confused for one another.24 Bone modeling refers to the change in size, shape, or position of bones in response to a mechanical stimulus such as loading or wounding. It is biomechanically controlled and is the physiologic mechanism in which bone responds to functional loading.25 Remodeling is the physiologic replacement of mineralized tissue without changing the size or shape of the tissue. Remodeling is a coordinated activity that balances the resorption and deposition of bone and is integral in maintaining calcium homeostasis and repairing damaged mineralized tissue.25

The significance of remodeling and miniscrew implantation is that the rate and duration of remodeling is increased surrounding an implant. Human bone remodels at a rate of 2 to 10 percent per year.23 Roberts23 noted that remodeling around an implant to be about twenty percent per year. Remodeling is an expected bone response to the trauma sustained upon implant placement and is part of the normal healing process. The unique aspect of the increased remodeling rate is that it is sustained well beyond the normal healing time required and is a unique aspect of long term bone adaptation to implants.22
Titanium and cortical bone differ greatly in their modulus of elasticities. Cortical bone has a modulus of 13.4 Gpa and titanium has a modulus of 104 Gpa.\textsuperscript{26} Due to the differing elasticities, the stiffer titanium implant could potentially create stresses in the surrounding bone, leading to fracture of the bone. Garretto\textsuperscript{27} suggests that the elevated rate of remodeling surround the implant prevents the fracture of bone from occurring. The elevated remodeling removes damaged devitalized bone at the interface and makes the bone more compliant. The softer, compliant bone reduces stress concentration and prevents fractures from occurring.\textsuperscript{28} In addition, the implantation procedure leads to microcracks in the bone surrounding the implantation site. The microcracks are removed via remodeling. Huja\textsuperscript{29} claims that the sustained remodeling around implants keeps the bone from undergoing secondary mineralization and keeps the bone compliant.

There are some differences in bone adaptation to miniscrew insertion between the maxilla and mandible. The differing responses are directly related to the thickness of cortical bone\textsuperscript{22} and forces of mastication that vary depending on location in the jaw.\textsuperscript{30} Masticatory forces create strain on the surfaces of the maxilla and mandible. When an implant is placed, a hole is created in the surface of the bone, and the strain is then concentrated around the implant. The maxilla responds to this initial strain by modeling. It deposits bone to increase bone volume which serves to dissipate strain within the bone. As bone volume increases, strain levels decrease and equilibrium is reached between strain and bone volume. Once equilibrium is reached, the maxillary bone then undergoes remodeling around the implant. In the mandible, the cortical bone is thicker and is able to dissipate strains more readily than the maxilla. As result the mandibular bone does not
respond by bone modeling, rather it responds immediately by remodeling around the implant.\textsuperscript{22}

Treatment Planning

Miniscrews are indicated when the correction of dental or skeletal disharmonies requires more anchorage then available or the clinician wishes to avoid reciprocal effects on neighboring teeth. They can be placed in patients of any age, with the primary requirement being the presence of bone of adequate quantity and quality.\textsuperscript{31} In a review article by Huang\textsuperscript{32} et al, some common indications for miniscrew placement are: intrusion or extrusion of teeth, closure of edentulous spaces, reinforcement of existing anchorage, orthopedic movements, and the correction of undesirable occlusions. Cope\textsuperscript{31} lists some common contraindications to miniscrew insertion: local active infection, radiation therapy, metabolic bone disorders, uncontrolled periodontitis, bisphosphonate therapy, oral mucosal pathologies, poor oral hygiene, parafunctional habits and inadequate patient compliance.

Once the decision is made to utilize a miniscrew, the clinician needs to determine possible placement locations within the maxilla and mandible. Poggio\textsuperscript{33} et al. used 3D cone beam technology to construct an anatomical map of bone depths between dental roots in the maxilla and mandible. Poggio used the NewTom System to take volumetric tomographic images of 25 maxillae and 25 mandibles. Interradicular buccolingual and mesiodistal distances distal to the canines were measured at two, five, eight, and eleven millimeters from the alveolar crest. Results for the maxilla showed the greatest mesiodistal bone on the palatal side between the first molar and the second premolar,
with 5.5 mm of bone at a level of 5 mm below the alveolar crest. When implanting on
the buccal of the maxilla, the greatest amount of mesiodistal bone is between the first and
second premolars with an average of 3.5 mm of interradicular distance. The greatest
buccolingual bone was 14.3 mm found 5 mm from the alveolar crest between the first and
second molars. Overall there is more space for miniscrews on the palatal side of the
maxilla as compared to the buccal side. In the mandible, the greatest mesiodistal distance
was found between the first and second premolars with 4.9 mm at 11 mm from the
alveolar crest. The greatest buccolingual distance was 13.4 mm at 8 and 11 mm depths
between the first and second molars. In both the maxilla and the mandible the
mesiodistal interradicular distances are smaller than the buccolingual, they therefore are
the key in determining an adequate miniscrew site.

Poggio’s study showed that maximal mesiodistal interradicular bone is generally
found 5-8 mm below alveolar crest in the maxilla and 11 mm below the alveolar crest in
the mandible. Placing a miniscrew at these levels will often place the miniscrew in
movable alveolar mucosa as opposed to keratinized tissue. This has been shown to be a
source of soft-tissue irritation to the patient and a may lead to greater occurrence of
infection.17 Warrer34 showed that lack of keratinized tissue around an implant may
increase the tissues susceptibility to plaque induced tissue destruction. Cope31 suggests
that the placement of miniscrews into mobile unattached mucosa is not necessarily
contraindicated. He advocates a more rigorous oral hygiene regime and says that this
will prevent tissue infection. Cope is more concerned with placing the miniscrew into
adequate bone and feels with proper hygiene the implants will not fail.
Miniscrew Applications

As miniscrew placement becomes more routine in orthodontics, their versatility and usefulness becomes more evident. A review of recent literature describes a multitude of case reports and studies which illustrate clinical applications for miniscrews. Some common clinical applications of miniscrews include the correction of deep bites, closure of extraction spaces, correction of occlusal plane cants, extrusion of impacted teeth, uprighting of molars, mesialization and distalization of molars, and correction of vertical skeletal discrepancies.

In 2005, Ohnishi\textsuperscript{35} et al. described the use of miniscrews to correct a severe deep bite. The patient in this case report was a 19 year old female with excessive gingival display on high smile, 7.2 mm of overbite and 4.8 mm overjet. The treatment plan called for intrusion of upper incisors in order to correct the deep bite and reduce gingival display while maintaining the Class I molar relationship. A 1.2 mm diameter by 6 mm in length miniscrew was placed between the maxillary central incisors, 3 mm above the root apices. The miniscrew was allowed to heal for six months and then an abutment was placed. Two months following the placement of the abutment, a ligature wire was attached and used to intrude the incisors. A light force of 20 grams was applied to the central incisors for 15 months and the overbite was reduced to 1.7 mm and overjet decreased to 2.6 mm. The implant remained stable until removal at end of treatment. The gingival display was reduced and the molars maintained their Class I relationship. Radiographs taken post treatment did not indicate any abnormal root resorption of the central incisors.
Anchorage intensive procedures, such as the closure of edentulous spaces, benefit greatly from the incorporation of miniscrews. Park\textsuperscript{36} published a case report in which maximum retraction of anterior teeth was desired following the extraction of four first bicuspid in a bimaxillary protrusive patient. In this case, a twenty year old female presented with a chief complaint concerning her excessive lip protrusion, related to the severe labial inclination of her incisors. A diagnosis of bimaxillary protrusion called for the extraction of four first bicuspid. A 2 mm in diameter by 7 mm in length miniscrew was placed buccally between the second premolar and first molar in each quadrant. Retraction of anterior teeth was accomplished with elastics from the miniscrews to the anterior segments. After six months the anterior segments were retracted to within 1 mm of complete space closure. Total treatment time was 14 months. The upper lip retracted 3.8 mm and the lower lip retracted 5.8 mm while maintaining the patient’s initial Class I molar and canine relationship.

Treatment plans that would traditionally require extractions to correct a malocclusion may be converted to a non-extraction plan with the use of miniscrews. Park\textsuperscript{37} describes two such cases. In the first case, a 28 year old female presented with the chief complaint of “crooked front teeth.” The patient had a good soft tissue profile, angle Class I molar relationship, 2 mm overjet, 1 mm overbite, 4 mm crowding in the maxillary arch and 5.5 mm crowding in the mandibular arch. The decision was made to treat this patient non-extraction with four miniscrews, one in each quadrant, to distalize the maxillary and mandibular molars and provide space to resolve the anterior crowding. 1.2 mm diameter implants with lengths of 6-10 mm were used. In the maxilla, two implants were placed palatally between the first and second molars and in the mandible they were
placed distobuccal to the second molars. Two weeks after placement, the implants were activated with elastomeric threads to distalize the posterior dentition. Total treatment time was ten months. The crowding in both arches was resolved, maintaining the Class I molar relationship and the soft tissue profile.

In a second case, Park\textsuperscript{37}, once again used miniscrews to resolve arch length deficiencies, this time in a growing patient. A 13 year-old male presented with Class I molar and canine relationship, 6 mm of crowding in the maxillary arch and 4 mm of crowding in the mandibular arch. Park placed 1.2 mm diameter by 8 mm long miniscrews bilaterally in the maxilla between second premolar and first molar. In the mandible, he placed 1.2 mm by 6 mm miniscrews bilaterally in the retromolar area. Two weeks following miniscrew placement, NiTi coil springs and elastomeric chains were attached to the canines in all four quadrants. Anterior space was created by the en masse distalization of all posterior segments. The maxillary posterior teeth were retracted 2 mm and the mandibular teeth were retracted 2.5 mm. The treatment time was 17 months and the soft tissue profile was maintained as was the class I dental relationships.

Thiruvanekatchari\textsuperscript{38} compared anchorage loss during canine retraction between canines retracted using molars as anchors versus those retracted using miniscrews as anchors. The study included ten patients with average age of 19.6 years who needed premolar extraction and maximum anchorage for anterior segment retraction. Miniscrews were placed between second premolar and first molar in the selected quadrant. Nickel titanium coil springs were connected between the molar and canine on one side and between the implant and canine on the other side. Therefore each patient had one implant anchored side and one molar anchored side to allow for comparison
within each patient. The coil spring applied 100 grams of force and was activated 15 days after miniscrew placement. Molar anchorage loss was determined by superimposing lateral cephalograms. The canines were fully retracted after 4-6 months on both sides of all subjects. Superimpositions showed no anchorage loss on the implant anchored sides. The molar anchored sides showed a statistically significant average anchorage loss of 1.6 mm in maxilla and 1.7 mm in the mandible. The author of the study concluded that miniscrews can be used successfully to retract canines without anchorage loss.

Mesially tipped mandibular second molars often cause extrusion and movement of anchor segments when attempting to upright them. As a result clinicians have begun using miniscrews as anchors to upright molars which eliminates the reciprocal effects on the rest of teeth in the arch. Yun described the use of miniscrews to upright mesially tipped second molars. The procedure requires one miniscrew to be placed on the buccal side of the arch with the tipped molar. A rigid stainless steel wire is attached to the miniscrew and bonded to the buccal surface of the first molar. This in effect fixes the first molar to the bone as if it is ankylosed. Then an uprighting spring is run from the first molar to the second molar. As the second molar uprights, the first molar is firmly held in place by the skeletal anchor.

Giancotti used a retromolar miniscrew to upright and extrude a deeply impacted mandibular second molar. In his case report, a 27 year-old patient presented with good occlusion but was found to have an impacted lower left mandibular molar and over erupted lower left third molar. The treatment plan called for the extraction of the third molar and the uprighting and extrusion of the second molar with the help of a retromolar miniscrew. The third molar was extracted and a 7 mm miniscrew was placed distal to the
impacted second molar. A nickel titanium closed coil spring was immediately attached from the miniscrew to the second molar and applied 50 grams of force to the second molar. Molar uprighting and aligning was completed in eight months and the miniscrew was still stable upon removal.

When teeth overerupt into opposing edentulous areas, they may prevent the placement of a replacement dental unit into the edentulous area. Lin illustrates the use of miniscrews to intrude overerupted teeth and provide clearance for the restoration of the edentulous area. A 26 year-old female patient is presented with an upper left second molar that has extruded 5 mm into the space of a missing lower left mandibular second molar. The extruded molar did not allow for an implant crown to be fabricated to replace the lower left second molar. Lin used miniscrews to intrude the extruded second molar. Two 1.5 mm diameter by 9 mm long miniscrews were placed in the maxillary buccal alveolar bone, one in the tuberosity and one between the first and second molars. A third 2 mm by 7 mm long miniscrew was placed in the palate between the first and second molars. Immediately following miniscrew placement 150-200g of intrusive force was applied to the second molar via an elastic power chain. Intrusion took five months to complete and enough clearance was created for an implant crown to replace the lower left second molar. Periapical radiographs of the maxillary second molar did not indicate root resorption and the miniscrews remained stable throughout treatment.

Anterior skeletal open bites are some of the most difficult cases to treat in orthodontics. In adult patients, surgery is usually required to reposition the jaws in order to achieve a desired occlusion. Often times patients decline a surgical treatment plan in favor of a less than ideal camouflage treatment. The use of miniscrews has given
orthodontists the potential ability to obtain skeletal correction without orthognathic surgery.

Kuroda\(^4^3\) published a case report in which he used miniscrews to correct a severe anterior open-bite. A 33 year-old female presented with a severe anterior open-bite. She had 7.1 mm overjet, a negative 7.0 mm overbite, and an increased lower anterior facial height. Kuroda suggested that the etiology of this patients open bite to be a combination of extruded upper and lower molars and a backward rotation of the mandible. The treatment plan indicated the use of four 2.3 mm x 14 mm miniscrews to serve as anchors for the intrusion of the molars in the maxilla and mandible. Two miniscrews were placed in the zygomatic process of the maxilla and two were placed in the buccal bone apical to the mandibular first molars. The miniscrews were allowed to heal for three months before loading. They were the loaded with elastic chains for six months and intruded the molars 3 mm. Overbite was reduced to -1.0mm, a correction of 6mm. The intrusion of the molars allowed for a counterclockwise rotation of the mandible, which decreased the lower facial height and greatly improved the facial profile. The miniscrews remained stable from insertion until removal and were devoid of complications.

Park\(^4^4\) et al. advocated the use of miniscrews in the treatment of open bite cases for several reasons. In patients who require the extraction of bicuspid, the molars often tip mesially when closing extraction spaces. By using miniscrews to retract anterior teeth, the mesial tipping of molars can be prevented and the mesial movement of the molars is also controlled, resulting in anchorage preservation. The molars can also be simultaneously intruded, which can serve to close the mandibular plane. Another problem with open bite patients is that intermaxillary elastics are often needed but are
known to extrude the molars. Miniscrews can reduce or eliminate the need for intermaxillary elastics.

To illustrate the points above, Park described the treatment of a 24 year-old female with an anterior open bite. The patient presented with a convex profile, retruded mandible, high mandibular plane of 45 degrees, 5 mm overjet and -2.5 mm overbite. The patient was Class II molar on right side and Class III on the left with arch length discrepancies of 4.5 mm in the maxilla and 6.0 mm in the mandible. The treatment plan required the extraction of maxillary first premolars to resolve anterior crowding and improve the profile and the mandibular second premolars to move the mandibular posterior teeth forward in hope of moving the fulcrum forward, aided by the use of miniscrews to control anchorage. Maxillary miniscrew implants, 8 mm long by 1.2 mm in diameter, were placed interradicularly between the maxillary second premolars and the first molars. Mandibular implants, 6 mm long by 1.2 mm in diameter, were placed into the cortical bone of the mandibular arch between the first and second molars. The miniscrews were loaded with 150 grams of force two weeks after placement. The mandibular miniscrews were used to upright the molars and to protract them without retracting the anterior teeth. The maxillary miniscrews were used to retract the cuspids until anterior crowding was resolved. Elastic threads were used from the miniscrews to the molars in both arches to apply an intrusive force in attempt to close the bite. Treatment duration was 23 months and facial balance was achieved by retracting the maxillary anterior teeth and closing the mandibular plane after slight intrusion of the posterior teeth and forward movement of the mandibular posterior teeth with the uprighting. All screws remained stable throughout treatment.
Complications

The placement of miniscrews has proven useful to the orthodontist in obtaining skeletal anchorage. Though miniscrew placement is a relatively benign procedure, complications can arise during placement and after orthodontic loading in regard to stability and patient safety. To avoid any such complications, the clinician should have a thorough understanding of proper placement technique, bone landscape, peri-implant soft-tissues, regional anatomical structures, and patient home care needs. When complications do arise, they generally involve alveolar bone, tooth structures, and/or soft tissue which may result in miniscrew failure or patient injury.

Primary miniscrew stability upon placement has been shown to be critical for miniscrew success. Primary stability is achieved when the miniscrew is absolutely immobile immediately following placement. A lack of primary stability leads to miniscrew mobility which will lead to miniscrew failure. Failure to achieve primary stability is often a result of inadequate cortical bone thickness, over drilling the pilot hole, or overheating the bone when drilling the pilot hole. To help ensure adequate cortical bone thickness, one should use either Poggio’s or Schnelle’s anatomical guides as a general map for placing a miniscrew. Poggio and Schnelle studied bone thickness in the maxilla and mandible and compiled a list of the best insertion sites which have the most cortical bone available. In miniscrew placement protocols that indicate the need for a pilot hole, over drilling the hole can prevent primary stability. This is often due to changes in handpiece angulation when drilling. The latter can be prevented by maintaining a consistant handpiece orientation perpendicular to the insertion site when
making the pilot hole. Another potential cause of miniscrew instability is overheating the bone when making a pilot hole. When bone is heated to 47 degrees Celsius for more than one minute, necrosis of the bone margins may occur. This can be best avoided by using drill-free screws or using copious irrigation when drilling the pilot hole. Though the aforementioned complications may occur, the solution is to simply relocate the miniscrew to a new location.

One of the advantages of using miniscrews is that they are small enough to be placed interradicularly. The insertion of miniscrews in close proximity to tooth roots creates the potential of inadvertently either impinging or inserting one into a tooth root. A literature review reveals the incidence of root impingement to be very low and when it does occur, the sequelae are reported to be rather benign.

Borah and Ashmead investigated the incidence and sequelae of root impingement from rigid internal fixation screws used in the treatment of unstable facial fractures and for fixation of osteotomy sites. 387 patients consecutively treated for facial injury were reviewed for the study. Patient records and postoperative radiographs were examined to determine whether any teeth were transfixed by a screw. Patients, who were positively identified as having a transfixed tooth, were recalled for examination. The study included a total of 2300 fixation screws of which 13 were found to have transfixed a root. A dental vitalometer was used, which generated a small electrical stimulation that, when applied to the crown of a tooth, can stimulate a patient to feel a tingling sensation in a vital tooth. The vitalometer was used to test the vitality of all teeth identified as having been transfixed by a screw. The results of this study indicated that the incidence of root impingement to be 0.47% and all transfixed teeth tested as vital. More roots were
impinged in the mandible then the maxilla, presumably due to a thicker buccal plate which makes the identification of root contours more difficult to define. Teeth that were transfixed were shown not to become infected or need extraction and that the impingement of a root by a screw does not adversely affect the survival of a tooth.

Fabbroni et al.\textsuperscript{50} prospectively studied the incidence and clinical significance of screw to root contact in the placement of transalveolar screws. Transalveolar screws are placed interradicularly in the maxilla and mandible and are used for intermaxillary fixation to stabilize jaw fractures. Fabbroni looked at postoperative panoramic x-rays to determine if teeth may have been contacted by screws. When a possible root contact was seen on a panoramic x-ray, a periapical film was taken to assess the degree of screw impingement. Fifty-five consecutively treated patients were entered in the study. A total of 232 screws were placed to stabilize jaw fractures due to trauma. Sixty-three positive root contacts by screws were identified. Six of these tested as non-vital with an electronic pulp tester. None of the non-vital teeth needed extraction or root canal therapy as result of root impingement. Fabbroni notes that the six teeth may have been non-vital prior to placing the fixation screws and that vitality testing following jaw fracture is not very accurate. The overall conclusion of this study is that the incidence of root impingement is very low and the clinical consequences are negligible.

The placement of miniscrews requires that the clinician be cognizant of the surrounding soft tissues, as soft tissue complications may compromise the successful use of a miniscrew. A review of the literature lists soft tissue tearing, impingement, and infection as the most common potential soft tissue complications.
When the location of a miniscrew requires that it be placed through unattached gingiva, there is a potential for the loose tissue to tear. This often occurs when the tissue wraps around the pilot drill or miniscrew upon insertion and can be easily avoided by using a mucosal punch to create a placement window free of mobile soft tissue. Another, more invasive, alternative is to elevate a mucoperiosteal flap prior to miniscrew insertion. This affords the clinician an unobstructed view of cortical bone without interference from the unattached mucosa. Once a miniscrew is loaded, the clinician must evaluate the local soft tissues and their relationships to any attachments from the miniscrew. The tissues adjacent to the miniscrew are subject to trauma and irritation from poorly placed auxillary devices. The most common complication that occurs is soft tissue impingement of an auxillary device resulting in soft tissue overgrowth and/or ulceration. This may be controlled by changing the orientation of the auxillary device to keep them from applying pressure to the tissues.

Inflammation and infection of the tissues around a miniscrew are potential complications. Plaque accumulation around a miniscrew can lead to a reversible inflammatory change in the soft tissue that is analogous to gingivitis. In cases of inflammation around a miniscrew, removal of the miniscrew is not indicated if proper oral hygiene can be established. In addition to meticulous oral hygiene, a 0.2% chlorhexidine mouthrinse may be dispensed to aid in resolving inflammation. If the inflammation is not resolved, this may lead to a frank soft tissue infection and/or miniscrew failure. A localized infection will often present with pain, swelling, erythema, and purulence. Patients with an infection should be given chlorhexidine to use for 5 to 7 days. If the infection is not resolved in ten days, the miniscrew should be
removed and time given for the infection to resolve.\textsuperscript{31} Cope\textsuperscript{31} suggests that the clinician should use clinical judgment to determine if a patient should be prescribed oral antibiotics. In the event of progressive infection with purulence and fever, antibiotics should be administered.\textsuperscript{31}

Miniscrew Success Rates and Factors

A review of orthodontic literature shows that miniscrews can be used in a variety of applications to provide stable anchorage during orthodontic treatment. The ability of a miniscrew to provide anchorage is dependent on it remaining stable in bone. Several studies have been done in the last few years examining factors that influence miniscrew success. The identification of such factors should allow the clinician to better plan for the use of miniscrews and increase their overall success rate.

Miyawaki\textsuperscript{55} published one of the first studies to examine miniscrew success rates and the factors associated with their stability in bone. Miyawaki retrospectively reviewed the case histories for 51 patients who received miniscrews in the posterior buccal region of the maxilla and mandible. There were three sizes of miniscrews used with differing diameters and lengths (Type A: diameter, 1.0 mm; length 6 mm: Type B: diameter, 1.5 mm; length, 11 mm; Type C: diameter, 2.3 mm; length 14 mm). All miniscrews were loaded with a continuous force of 2 N. A miniscrew was deemed a success if it remained stable for either one year or until desired movement was achieved. There were a total of 10 type A screws, 101 type B screws, and 23 type C screws. The success rate for type A screws with a 1.0 mm diameter was 0.0%. Types B and C miniscrews had success rates of 83.9% and 85.0%, respectively. Patients who had a gingival flap raised to place the
miniscrew reported much more post operative discomfort and swelling. Patients with flapless insertion rarely complained of discomfort. Patients with a high mandibular plane angle showed significantly lower success rates that those with average or low angles. Miniscrews with inflammation of the tissues surrounding it, showed a significantly lower success rate then those without inflammation. Neither the location of the implant (maxilla or mandible) nor the period prior to loading was significantly associated with the success rate.

Miyawaki’s\textsuperscript{55} study was the first to associate diameter of miniscrew, peri-implant inflammation, and mandibular plane angle with a miniscrews success rate. The finding that peri-implant inflammation reduces the success rate agrees with Artzi\textsuperscript{56}, who found the same to be true for dental implants. Therefore, oral hygiene to prevent inflammation is of paramount importance. With respect to implant diameter, the results indicate that a miniscrew needs to have at least a 1.5 mm diameter to stabilize the miniscrew in the cortical bone. Miniscrews rely on mechanical retention\textsuperscript{31} and the miniscrews with less then 1.5 mm diameter, had insufficient retention resulting in a 100% failure rate. Masumoto\textsuperscript{57} examined the relationship between facial types and the thickness of the buccal cortical plate in the mandible. He found that people with long faces, high mandibular planes, had significantly thinner mandibular buccal cortical plates. This lack of cortical stability may explain why patients with a high mandibular plane had higher failure rates.

Park\textsuperscript{58} also examined the factors related to the clinical success of miniscrews. Park’s sample consisted of 87 consecutively treated patients who received a total of 227 miniscrews for anchorage. Four different types of miniscrews were placed that differed
in lengths and diameters. The diameters of the miniscrews ranged from 1.2-2.0 mm and the lengths ranged from 4-15 mm. All miniscrews were placed after raising a mucoperiosteal flap and they were checked for primary stability to rule out immediate failures. The overall success rate of the 227 miniscrews was 91.6%. The average period of force application was 15 months. Of the 19 miniscrews that failed, 11 replacements were successful until the end of force application. In contrast to Miyawaki’s \cite{Miyawaki55} findings, Park found no statistically significant differences in the success rates between diameter and length of the screws, but all of his miniscrews were greater then 1.0 mm in diameter. For host factors, there were no differences according to patient age or sex. Miniscrews in the maxilla had a higher success rate than those placed in the mandible, presumably because of the heat generated by inserting the miniscrew into the thicker mandibular bone. Park also found inflammation to significantly reduce the success rate of the miniscrew.

Wiechmann \cite{Wiechmann59} recently published a prospective clinical study to evaluate the success rate of two types of miniscrews. The study included 49 consecutively treated patients who required the use of miniscrews for orthodontic anchorage. A total of 133 miniscrews were placed. Two diameters of miniscrews were used, 1.1 mm and 1.6 mm. All miniscrews were loaded immediately and observed for 120 days. The results showed that 31 of the 133 implants had clinically detectable mobility and had to be removed. Eleven of the failures were on the lingual of the mandible and these had a failure rate of nearly 100%. The 1.1 mm diameter miniscrews had a 30.1 % failure rate whereas the 1.6 mm miniscrews had a failure rate of 13%. This finding agrees with Miyawaki’s \cite{Miyawaki55} who also found a higher success rate with larger diameter miniscrews. Wiechmann found a higher
success rate in the maxilla as compared to the mandible which is consistent with the findings of Miyawaki\textsuperscript{55} and Park.\textsuperscript{58}

Tseng\textsuperscript{60} investigated the overall success rate of miniscrews and identified risk factors associated with miniscrew failure. In this study, all miniscrews were 2.0 mm in diameter and only the length varied from 8-14 mm. A total of 45 miniscrews were placed in the maxilla and mandible. The overall success rate was 91.1%. The only significant risk factor identified in this study was location of the miniscrew. The posterior mandible was positively associated with increased failure rate. Kuroda\textsuperscript{61} offers some possible reasons for the increase failure of miniscrews in the posterior mandible. First, access to the posterior mandible can be difficult leading to less than ideal surgical technique. This region also has less attached gingiva and a narrow vestibule which makes oral hygiene more difficult. With decreased hygiene, the miniscrews are more susceptible to failure due to peri-implant inflammation. Tseng\textsuperscript{60} concurs with Kuroda\textsuperscript{61} that difficulty in maintaining ideal oral hygiene in the posterior mandible makes the miniscrew more susceptible to failure. Tseng also suggests that the miniscrews in the mandible receive more forces from mastication which may increase their mobility and lead to subsequent failure. Tseng concludes that overall, that miniscrews are successful and useful as adjuncts for obtaining orthodontic anchorage.
SUCCESS RATES OF TEMPORARY ANCHORAGE DEVICES PLACED IN AN
ORTHODONTIC CLINIC

by

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ABSTRACT

In recent years, the use of a variety of temporary placed implants to attain absolute anchorage has been described in the orthodontic literature. The use of temporary implants, fixed to bone, overcomes some of the limitations of traditional anchorage and their reliance on patient compliance. The purpose of this study was to evaluate factors relating to the successful placement of miniscrew temporary anchorage devices in an orthodontic clinic. The orthodontic records of patients who had miniscrews placed during their treatment at the University of Alabama at Birmingham School of Dentistry Postgraduate Orthodontic Clinic were selected. After application of the inclusion and exclusion criteria, the final study sample consisted of 32 patients who received a total of 58 miniscrew anchorage devices. The records of all 32 patients were analyzed to determine implant site, time before implant loading, experience level of clinician placing the implant, and whether the implant remained stable during the loading period. In addition, a vitality test was performed on each patient to determine the vitality of all the teeth in the quadrant where the miniscrew was placed. The overall success rate was 75.8%. Miniscrews placed in the maxilla were clinically more successful than those placed in the mandible. There was no statistically significant difference in time before miniscrew loading, patient age, and experience level of clinician. Following adjustment for multiple implant failures and successes in individual patients, experience level of the clinician placing the miniscrew became statistically significant. The experienced clinician had a greater expectation of success than the novice group. In addition, 100%
of the teeth tested as vital. These results indicate that the placement of miniscrews can be accomplished successfully in an orthodontic clinic. This study also suggests that there is a learning curve to the placement of miniscrews and orthodontic clinicians can expect their success rates to increase as they place more miniscrews.
INTRODUCTION

Sir Isaac Newton provided the basis for classical orthodontic mechanics with his three laws of motion. His third law states that for every action there is an equal and opposite reaction. This statement has proven to be of utmost relevance to orthodontic treatment and more specifically to orthodontic anchorage. Orthodontic anchorage is defined as the resistance to unwanted tooth movement. Orthodontists attempt to move specific teeth while preventing the reciprocal effects of forces on other teeth. Traditionally, the control of unwanted tooth movement has been attempted with a variety of extra and intraoral devices. These appliances are often uncomfortable, awkward, and unaesthetic. As result, patient compliance is often less than ideal which can compromise treatment outcomes. In recent years, the use of a variety of temporary placed implants to attain absolute anchorage has been described in the orthodontic literature. The use of temporary implants, fixed to bone, overcomes the limitations of traditional anchorage and their reliance on patient compliance.

The use of temporary anchorage devices (TADs) was first described by Gainsforth and Higley in 1945 and attempted clinically by Creekmore and Eklund in 1983. In the years following the work of Creekmore and Eklund, orthodontists have published numerous case reports and studies introducing various TAD designs and systems. Miniscrews, miniplates, retromolar implants, palatal implants, fixation wire implants and palatal onplants are some of the implant systems that have been used in clinical orthodontics.
As the use of temporary anchorage devices becomes a routine modality of treatment, studies have examined potential complications due to their placement. Complications such as: root impingement\textsuperscript{12, 13}, infection\textsuperscript{14}, soft tissue tearing\textsuperscript{15}, and gingival inflammation\textsuperscript{15, 16} have been described. One of the most common clinical concerns when placing intraradicular implants is root damage. Borah and Ashmead\textsuperscript{12} and Fabbroni et al.\textsuperscript{13} investigated the incidence and consequences of root impingement by surgical screws. Both studies found the incidence of root impingement to be very low and of negligible clinical consequence. Papadopoulos\textsuperscript{14} reviewed soft tissue complications and found soft tissue impingement, ulceration, and inflammation to be common occurrences, but noted that they are often minor and reversible. Cope\textsuperscript{15} suggests that soft tissue complications can be limited by proper orientation of auxiliary devices connected to implants, and by rigorous oral hygiene.

The effectiveness of temporary anchorage devices in providing absolute anchorage has been well documented.\textsuperscript{16, 17,18,19,20,21} Their efficacy is directly related to the successful placement of them into the mouth. Miyawaki\textsuperscript{17} published one of the first studies to examine temporary implant success rates and the factors associated with their stability in bone. He found success to be directly related to implant diameter, peri-implant tissue health, and thickness of the bone. Park\textsuperscript{18} concurred, and also found inflammation to significantly reduce the success rate implants. Park\textsuperscript{18}, Wiechmann\textsuperscript{19} and Miyawaki\textsuperscript{17} all found implants to be more successful in the maxilla as compared to the mandible and all agreed that peri-implant tissue health was directly correlated to implant success. Most recently Tseng\textsuperscript{20} and Kuroda\textsuperscript{21} found that the posterior mandible had the
highest failure rate, but both concluded that temporary anchorage devices are successful and useful as adjuncts for obtaining orthodontic anchorage.

The purpose of the present study was to evaluate factors relating to the successful placement of miniscrew temporary anchorage devices in an orthodontic clinic. The orthodontic records of patients who had miniscrews placed during their treatment at the University of Alabama at Birmingham School of Dentistry Postgraduate Orthodontic Clinic were selected. After application of the inclusion and exclusion criteria, the final study sample consisted of 32 patients who received a total of 58 miniscrew anchorage devices. The records of all 32 patients were analyzed to determine implant site, time before implant loading, experience level of clinician placing the implant, and whether the implant remained stable during the loading period. In addition, a vitality test was performed on each patient to determine the vitality of all the teeth in the quadrant where the miniscrew was placed.

MATERIALS AND METHODS

The study sample was obtained from the records at the University of Alabama at Birmingham School of Dentistry Postgraduate Orthodontic Clinic. Patients whose treatment included the use of a miniscrew temporary anchorage device were identified. The inclusion criteria for the study required that the patient received at least one miniscrew placed in the orthodontic clinic by an orthodontist or orthodontic resident. Subjects were excluded if they had a miniscrew placed in a clinic other then the orthodontic clinic. The final sample consisted of 32 patients and a total of 58 miniscrews.
The following information was gathered from the patient’s treatment records: patient age, miniscrew site, dates of miniscrew placement, loading and removal, and clinician who placed the miniscrew. From this information the numbers of days the miniscrews were loaded and present in the mouth were calculated. It was also determined whether the miniscrew was loaded immediately after placement or if loading was delayed. A miniscrew was considered successful if it remained stable until completion of the required orthodontic loading. A miniscrew was also considered a success if, at the time of this study, it was still stable and had been under an orthodontic load for greater than 300 days.

Clinicians placing miniscrews were divided into two groups: novice and expert. The novice group consisted of orthodontic residents and orthodontists placing miniscrews for the first time or having placed fewer than 5 miniscrews. The expert group consisted of one faculty member who had placed more than 50 miniscrews prior to the study.

All 32 patients received an ice test to determine the vitality of all teeth located in the same dental quadrant as the miniscrew. A cold cotton tip applicator was applied to each individual tooth to elicit a thermal response. If the patient indicated a positive cold sensation without lingering discomfort, the tooth was deemed vital or otherwise undamaged by the miniscrew.

**Statistical Analysis**

Categorical variables for the sample were compared between success and failure using a chi-square analysis. Means and standard deviations were calculated for the patient’s age, number of days the implant was loaded, implant site, delayed or immediate
loading, and level of operator experience. A logistical regression model using a GEE method to account for the clustering among patients was used to determine statistical interaction. P-values were determined at the 95% confidence level. All analysis was performed using SAS v 9.1.3.

RESULTS

The sample characteristics of the failed and successful miniscrews can be found in Table 1. There were a total of 58 miniscrews placed, of which 14 failed. The overall success rate was 75.8%. With respect to implantation site, 79.41% of the miniscrews placed in the maxilla were successful compared to 70.83% in the mandible. This difference was not statistically significant.

| TABLE 1. Sample Characteristics (* statistically significant at p<0.05) |
|------------------------|---------|---------|---------|----------|
|                       | N (%)   | Overall | Failed  | Success  | p-value  |
| Site                  |         |         |         |          |          |
| Mandible              | 24 (41.4)| 7 (29.17) | 17 (70.83) | 0.4521 |
| Maxilla               | 34 (58.6)| 7 (20.59) | 27 (79.41) |          |
| Loading               |         |         |         |          | 0.8318 |
| Delayed               | 20 (30.4)| 3 (15.0)  | 17 (85.0)  |          |
| Immediate             | 31 (53.45)| 4 (12.9)  | 27 (87.10) |          |
| Placed By             |         |         |         |          | 0.4312 |
| Experienced           | 32 (55.17)| 9 (28.13) | 23 (71.88) |          |
| Novice                | 26 (44.83)| 5 (19.23) | 21 (80.77) |          |
| Mean, (S.D.)          |         |         |         |          |          |
| Patient Age           | 22.5 (12.49)| 28.3 (14.63) | 0.1896 |
| Days Loaded           | 33.5 (41.77)| 296.86 (190.74)| <.0001 *|
The success rate for immediately loaded miniscrews was 87.1% and the rate for miniscrews in which loading was delayed was 85.0%. There was not a statistical difference between these two groups. Seven miniscrews failed prior to loading and were not included in the comparison between immediate and delayed loading groups. When considering the experience level of the clinician placing the miniscrew, there was no statistically significant difference between the novice and experienced groups. The average age of patients with failed miniscrews was 22.5 (S.D. 12.49). The average age of patients with successful miniscrews was 28.3 (S.D. 14.63). The difference of 5.8 years was not statistically significant. The successful miniscrews were loaded for an average of 296.86 (S.D. 190.74) days, whereas, the failed miniscrews were only loaded for 33.5 (S.D. 41.77) days. The difference of 263.36 days was statistically significant.

Some patients received more than one miniscrew which resulted in a clustering effect in the data. Multivariable analysis was performed using a logistic regression model with generalized estimating equations (GEE) to adjust for the clustering of the data. Statistical significance was indicated at \( p<0.05 \) (Table 2).

**TABLE 2.** Regression models using GEE to account for clustering among patients (* statistically significant at \( p<0.05 \))

<table>
<thead>
<tr>
<th>Site</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td></td>
</tr>
<tr>
<td>Mandible</td>
<td>0.0701</td>
</tr>
<tr>
<td>Placed By</td>
<td></td>
</tr>
<tr>
<td>Experienced</td>
<td>0.0222 *</td>
</tr>
<tr>
<td>Novice</td>
<td></td>
</tr>
<tr>
<td>Patient Age</td>
<td>0.1807</td>
</tr>
<tr>
<td>Days Loaded</td>
<td>0.0207 *</td>
</tr>
</tbody>
</table>
One patient had 4 miniscrews fail which accounts for 28.5% of the failures. Three other patients had more than one miniscrew fail. When accounting for the fact that some patients had multiple miniscrews either fail or succeed, the level of experience of the operator becomes significant ($p=0.0222$), which indicates a higher expectation of success for the experienced operator. Implant site and patient age remained statistically insignificant. The number of days the miniscrew was loaded remained significant ($p=0.0207$).

A total of 352 teeth in 32 patients were tested for vitality via an ice test. All 352 teeth had a positive thermal response, indicating that 100% of the teeth, located in the same dental quadrants as the miniscrews, remained vital.

DISCUSSION

The purpose of this study was to evaluate factors relating to the successful placement of miniscrew temporary anchorage devices in an orthodontic clinic. This was accomplished through the examination of patient records at the University of Alabama at Birmingham School of Dentistry Postgraduate Orthodontic Clinic. The records of patients who had received at least one miniscrew in the Orthodontic department were selected. The inclusion criteria required that the miniscrew be placed by an orthodontist or orthodontic resident in the orthodontic clinic.

The sample was limited only to miniscrews placed in an orthodontic clinic in order to evaluate any clinical factors that might be of relevance to the practicing orthodontist when placing miniscrews. Miniscrews placed by periodontists or oral surgeons were excluded because they are most often placed in a surgical setting which is
somewhat different than the open bay atmosphere of most orthodontic clinics. The final
sample size included 32 patients and a total of 58 miniscrews. From the patient records
the following characteristics were evaluated: miniscrew site, time before loading,
experience level of the operator placing the miniscrew, patient age, and number of days
the miniscrew was loaded.

The overall success rate of miniscrews in our sample was 75.8%, which is lower
than previous reports$^{20, 21}$. Tseng$^{20}$ reported a 91.1% success rate and Park$^{18}$ showed a
91.6% success rate. One possible explanation for the reduced overall success rate in this
study is that the miniscrews were placed in an educational environment. The clinicians
placing the miniscrews in our study included an experienced operator who was
instructing novices on the placement of miniscrews. It is natural to expect a novice
operator to have more potential failures because they are learning proper placement
techniques such as miniscrew driver angulations, speed of insertion, appropriate insertion
torque and soft tissue management. Park and Tseng’s studies had one experienced
operator placing all of the miniscrews.

In previous studies$^{17, 18, 19, 20, 21}$ it has been shown that miniscrews placed in the
maxilla were more successful than those placed in the mandible. The present results
concur with previous authors in that it was found that a clinically significant higher rate
of success with maxillary miniscrews (80%) than with mandibular miniscrews (70%),
though the differences were statistically insignificant. Kuroda$^{21}$ discussed some reasons
for reduced success in the mandible. First, access to the posterior mandible can be
difficult leading to less than ideal surgical technique. This region also has less attached
gingiva and a narrow vestibule which makes oral hygiene more difficult. With decreased
hygiene, the miniscrews are more susceptible to failure due to peri-implant inflammation. Tseng\textsuperscript{20} concurred with Kuroda\textsuperscript{21} that difficulty in maintaining ideal oral hygiene in the posterior mandible makes the miniscrew more susceptible to failure. Tseng\textsuperscript{20} also suggested that the miniscrews in the mandible received more forces from mastication which may increase their mobility and lead to subsequent failure.

In the present study, the success rates for immediately loaded (87.1\%) and delayed loaded (85.0\%) miniscrews were nearly the same. This agrees with results reported in previous studies\textsuperscript{14,18,20,21} in which immediate loading was shown to be as successful as delayed loading. This is significant because the clinician can commence orthodontic traction immediately upon miniscrew placement and thereby potentially shorten treatment time when compared to earlier protocols\textsuperscript{3,8,11,9} which called for a healing period prior to loading of the miniscrew.

The data in Table 1 indicates that novice operators actually had a higher success rate than the experienced clinician. This may be misleading for several reasons. The experienced clinician carefully selected cases for the novice operator to place miniscrews. Cases were selected based on expected ease of miniscrew insertion with respect to miniscrew location and patient cooperation. The experienced clinician was charged with the task of placing miniscrews in challenging locations such as the posterior mandible, which has been shown to have the lowest success rates.\textsuperscript{18,19,20,21} Case selection may have skewed the overall success rates for the two groups because the experienced clinician placed miniscrews in the majority difficult cases.

When evaluating the data set, it becomes apparent that some patients had multiple miniscrew failures. Four patients accounted for 71.4\% of the total failures, and
statistical regression model was constructed to account for this (Table 2). Table 2 indicates that the experience level of the operator is statistically significant, meaning that experienced clinicians can expect more successes than novice clinicians. With a sample of this size it is difficult to quantify how much more successful an experienced operator is in comparison to a novice. In this study, the experienced operator had placed more than 50 miniscrews and the inexperienced group was placing them for the first time. This simply shows that clinicians can expect to see their level of success increase as they place more miniscrews.

Patient age does not appear to influence the success rates of miniscrew placement. The age range of patients in this study was from 14-61 years of age and the difference in ages between the successful and failed groups was not statistically significant. Cope\textsuperscript{15} says that the primary criterion for miniscrew success is adequate bone, and that any patient, regardless of age, with adequate bone is eligible for miniscrew implantation. The present results support Cope’s assertion.

A statistically significant finding was the difference in the number of days the miniscrews were loaded in the successful and failed groups. Miniscrews that were mobile upon orthodontic loading were considered a failure and removed. The average number of days a failed miniscrew was in the mouth was only 33 days. Miniscrews that remained stable with orthodontic loading were loaded for an average of 296 days. This finding makes sense because if a miniscrew was stable under loading, it was loaded until the desired movement was achieved.

Recent studies have shifted focus from the efficacy of miniscrews to potential complications\textsuperscript{12,13,14,15,22}. The placement of miniscrews intraradicularly creates concern
regarding potential damage to the roots of neighboring teeth. To determine vitality, we conducted an ice test, after miniscrew placement, on every tooth in the dental quadrant in which the miniscrew was placed. A total of 352 teeth were tested for vitality, with 100% of the teeth having a normal positive thermal response. This was a simple method to determine whether miniscrews caused any significant pulpal changes, which may possibly be indicated by an exaggerated thermal response. This test did not indicate whether there was damage to the PDL. This study did not examine PDL damage because it has been previously shown that the PDL will repair itself if contacted by a miniscrew.23 Our results indicate that miniscrews can safely be placed in proximity to the roots.

CONCLUSIONS

The findings of this study illustrate the efficacy of placing miniscrews in an orthodontic clinic and the following conclusions can be made:

- Miniscrews can be placed with success in the maxilla and mandible with the maxilla having a slightly higher success rate.
- Miniscrews can be loaded immediately.
- Miniscrew can be placed in patients 14-61 years of age as long as adequate bone is available.
- Miniscrews can be placed with a high rate of success by novice operators.
- Experienced clinicians can expect more successes than novices.
REFERENCES


9. ITI/Straumann Orthosystem [product brochure].


CONCLUSIONS

The results of the present study illustrate the efficacy of miniscrew temporary anchorage devices placed in an orthodontic setting. Some of the first temporary anchorage devices were placed in a surgical setting by oral surgeons and periodontists. This increased costs to the patient, in addition to the inconvenience of having to see other specialists. The present results show that miniscrews can be placed by orthodontists in both the maxilla and mandible and in patients of all ages, as long as adequate bone is available with predictable success. Also, orthodontic traction can be applied immediately after miniscrew placement without a reduction in success, which increases treatment efficiency.

The present study compared the results of an experienced clinician with those of a group of novices. The number of miniscrews the experienced operator had placed prior to this study was estimated. The number may have differed from our estimate, but even so, he was clearly more experienced then the novice group. It would be interesting to track a single clinician’s progress from the first miniscrew placed to his or her hundredth placement and try to determine when one can expect to see an increase in the rate of success. An interesting finding in this study was the fact that even beginners can expect a fairly high rate of miniscrew success. Also, when failures do occur, the clinical consequences are rather benign. The miniscrew is simply removed and replaced with little or no discomfort or consequence to the patient. This study supports the placement of miniscrews by orthodontists in the orthodontic clinical setting.
GENERAL LIST OF REFERENCES


13. ITI/Straumann Orthosystem [product brochure].


APPENDIX A

INSTITUTIONAL REVIEW BOARD FOR HUMAN USE APPROVAL FORM

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56 and ICH GCP Guidelines. The Assurance became effective on November 24, 2003 and expires on February 14, 2009. The Assurance number is FWA00005960.

Principal Investigator: SCHREIBER, ALEX C
Co-Investigator(s): 
Protocol Number: X060626007
Protocol Title: Success Rates of Temporary Anchorage Devices Placed in an Orthodontic Clinic

The IRB reviewed and approved the above named project on 7-11-07. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.
IRB Approval Date: 7-11-07
Date IRB Approval Issued: 7-11-07
HiPAA Waiver Approved?: No
Marilyn Doss, M.A.
Vice Chair of the Institutional Review Board for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.