A Comprehensive Survey on the Use of Temporary Anchorage Devices in Orthodontics in the United States

by

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DEDICATION

I'd like to dedicate this thesis to my family. My dad, Dr. Darrell Clark has been a role model and my inspiration for hard work and determination professionally and personally. My mother, Dr. Maxine Clark, has helped guide my interest and watered them at every turn. To my brother, Dr. Brian Clark, my first and best friend. Thank you for your support and love. To my sister, Danielle Clark, I hope to be a role model and strong support for you as you embark on your dental school journey. To my girlfriend, Dr. Danielle Miller, your spirit, warm heart and smile makes every day brighter. Thank you for your support and words of encouragement.

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A COMPREHENSIVE SURVEY ON THE USE OF TEMPORARY ANCHORAGE DEVICES IN ORTHODONTICS IN THE UNITED STATES

Abstract

By

Robert Lauriston Clark

Introduction

The purpose of this study is to discover the demographics of the orthodontists placing TADs, evaluate the current use of TADs in the United States, determine what factors influence the adoption of TADs, and determine how TADs are used in practice.

Methods

A pilot survey was created using REDcap® software through Case Western Reserve University and distributed to 10 practicing orthodontists in the US. Using the feedback a 29 question survey was recreated to better gather data for analysis. Once the survey was finalized then a duplicate survey for a test retest reliability survey. The test retest reliability survey was distributed to 10 participants, and then retaken 3 weeks following their initial survey submission. The test retest reliability results will detail the stability of the scores across time. Simultaneously, the primary 29 question survey was

distributed to practicing orthodontists in the United States via Facebook, Instagram, mail, and at AAO regional conferences. The distribution material contained directions to access the enclosed survey link or QR code. Once the survey distribution was completed, the data was analyzed for correlations and causality using SPSS statistical software.

Results

Of the 245 total viable surveys taken from the data sample 57.1% use TADs, 24.1% previously used TADs, 23.3% never used TADs. In addition, 20.4% have been in practice for 1-5 years,19.6% have been in practice for 6-10 years, and 15.5% have been in practice for 30+ years. Of those that use TADs 65.9% received their training in TAD placement in a postgraduate setting. Of those that use TADs 44.2% have used TADs for maxillary posterior intrusion, 41.1% have used MARPE in their office.

Conclusion

Current TAD use by practitioners in the United States is popular with 57.1% of orthodontists using TADs in practice and 49.1% have an increased interest in continuing to use them at the same or higher rate over the next 5 years. When assessing factors that influence clinical adoption, most

orthodontists placing TADs received their training in a postgraduate setting (65.9%) and 66% placed at least 1 TAD in their post residency career. The most common group of orthodontists using TADs had 1 to 5 years practice and were owners/partners (20.4% and 62.7%, respectively). TADs have various uses to assist in achieving treatment planning goals. Maxillary expansion is the second most common way in which people use TADs (44.2%) behind maxillary posterior intrusion (41.1%). Fixed appliances in combination with TADs was the most common combination modality selected (66.7%).

TABLE OF CONTENTS

DEDICATION…….....ii
ACKNOWLEDGEMENTS….....iii
ABSTRACT…….....iv
REVIEW OF LITERATURE…….....1
LITERATURE REVIEW REFERENCES…….....…26
STATEMENT OF THESIS….....34
MANUSCRIPT FOR PUBLICATION….....…35
MANUSCRIPT REFERENCES.....66
APPENDICES
A. IRB APPROVAL…….....….71
B. ABBREVIATION KEY…….....72

REVIEW OF LITERATURE

History of screws

There is no historical evidence of who created the first screw. Yet, around 400 B.C.E. century, Archytas of Tarentum from Greece, was credited as creating the first screw to squeeze olives for oil and grapes for wine. Not long after, in the 3rd century B.C.E., Egyptians used Archimedes' Screw, from the Greek mathematician Archimedes, which assisted in the pumping of water uphill from the Nile.

Metal screws and nuts were later used in the 15th century to secure two objects together. In 1770, Jesse Ramsden invented the screw-cutting lathe. Henry Maudslay, followed in 1797 by inventing a large screw-cutting lathe making it possible to produce accurately sized screws on a large scale. In 1798, David Wilkinson invented machinery to produce threaded metal screws on a mass scale. Later in 1908 P.L. Robertson invented square-drive screws almost 30 years before Henry Phillips patented the Phillips head screws, which are also square-drive screws. The square-drive head allowed for the screwdriver to not slip out of the head when drilling. The square-drive screw became a North American standard as Published by the Industrial Fasteners Institute Book of Standards and Henry Ford's Ford Model Company used over 700 of Robertson's screws for its Model T car. As the

design of the screw continued to evolve, its application in various industries also evolved.

Fixation in orthopedics was first published in a French manuscript in 1775,where an iron wire was used for fixation of a bone fracture.[1] Throughout the 18th and 19th centuries the most common fixation technique was the use of cerclage wires to fix fractures.[1] Internal fixation was not a practical method of use due to the safety and high risk of sepsis. It was not until Lister, the father of asepsis, ensured the safety of open reduction and internal fixation making it possible to directly treat fractures in his 1867 publication.[1] In 1877, Lister successfully treated a patellar fracture using his antiseptic method to evenly fixate closed fractures using metal wires.[1,2,3] The technique was revolutionary and opened the possibilities of how fixation can be applied to other aspects of medicine. The use of fixation in traditional medicine eventually led to its fascination and potential in collaboration with orthodontic tooth movement and anchorage.

Defining orthodontic anchorage

Orthodontic anchorage was first clearly defined in 1923 by Louis Ottofy as “The base against which orthodontic force or reaction of orthodontic force is applied.”[4,5] Outlined categories of anchorage by E.H. Angle and others were summarized by Ottofy as simple, stationary, reciprocal, intraoral,

intermaxillary, or extraoral.[5] Moyer expounded on Ottofy's definition by outlining subcategories of extraoral anchorage.

Tweed incorporated anchorage into his treatment style by uprighting and distal tipping posterior molars to capitalize on the mechanical advantage before retracting anterior teeth.[4,6] In 2000, Daskalogiannakis defined anchorage as "resistance to unwanted tooth movement."[4,7] Many orthodontists have curated the idea of anchorage to support their philosophy as there has been a lack of consensus on the topic. In addition, Cope et al. points out, as orthodontics has evolved the classification systems for anchorage have been based on the times in which they were created. The possibility for intruding posterior teeth to correct a skeletal open bite without surgery was not fathomable. Yet, with advances in biology, materials, and clinical treatment what was once though unfathomable becomes reality; thus, leading to a new anchorage system.[4]

Limitations in orthodontic anchorage

As with any field of study, the accomplishments within that field are beholden to the technology, tools, and skill of the practitioner of that time. When looking back at our orthodontic predecessors their clinical achievements were based on and coincided with where the technology was at that time and what tools of that time could support. Fauchard in 1728

described an expansion arch which broadened the crowded dentition to a more normal form by using an ideal arch shaped metal plate attached to the teeth.[8] Occipital anchorage was professed by Gunnell in 1822 but details of the achievement were not detailed until 1841 and later refined by E.H. Angle in 1891.[9] In 1841, J.M.A. Schange improved on Christophe-Francois Delabarre's 1819 original design for the crib of Delabarre, which was attached to the palatal plate for anchorage and allowed for a labial arch and ligatures of silk or gold wires to achieve various tooth movements.[4,9] In addition to Angle's refinement of the occipital anchorage he also established the concept of stationary anchorage in 1887 and occlusal anchorage in 1891.[4,9]

Anchorage using TADs

In the early 20th century orthodontic movements were limited by their anchorage capabilities and bony fixation as a technique in the oral cavity had not been implemented. Temporary Anchorage Devices (TADs) permitted bony fixation and orthodontic anchorage like no other orthodontic instrument up to that time had achieved.

The use of TADs for anchorage was first published in 1945 by Gainsforth and Higley.[10] The article detailed how it was understood that "… the teeth selected for the anchorage often move simultaneously with those in which movement is desired." [10,..] And the study's aim was to achieve basal

bone anchorage by using vitallium screws placed in the ascending ramus of 6 dogs for retraction of upper canines.[10] The study used a 2.4mm pilot hole, and a 3.4 mm diameter x 13 mm long vitallium screw.[4,10] They then used a rubber band carrying between 140 to 200 g of force from the screw head to a 0.040 inch wire that slid through a tube on the upper molar band and was soldered to the upper canine band.[4,10] Yet, the screws failed in 16 to 31 days.[4] Although the authors did not disclose what the reason was it was possibly due to dynamic loading of the screws, infection, and lack of proper antibiotic management.[4]

Paralleling this development, in the late 1960s, Hans Luhr introduced maxillofacial surgery to the vitallium compression plate using the guiding screw technique to achieve compression across fractured segments. This made healing possible without the need for maxillomandibular fixation.[4,11] The fascination continued, into the 1950s when Brånemark showed chambers of titanium could become permanently fused and incorporated into bone so much so that the titanium oxide layer of the implant could not be separated without fracturing the implant.[12,13] Brånemark later coined the term “osseointegration” for this type of bone to metal integration where there is no progressive relative movement between the implant and the bone with which it has contact.[12,13] In 1969, Brånemark et al.showed that a titanium implant, when in the presence of good oral hygiene to prevent gingival inflammation, revealed good anchorage and potential unlimited masticatory load when there

was a non-traumatic surgical preparation, the implant was clean and mechanical in nature, and a mucoperiosteal barrier was reestablished.[12]

Several articles were published in the 1970s and 1980s meticulously testing osseointegrated implants in orthodontic treatment on animals.[14,15-33] During this period achievements were made such as, successfully executing stable implants when subjected to 60 g,120 g,and 180 g of force for 28 days, teeth were able to be moved using implants as orthodontic anchors, 6 mm palatal expansion was achieved, and 5 to 16 mm maxillary protraction was accomplished.[14,15-33] Furthermore, in the 1980s the first clinical application by In 1989, Block et al. concluded in their study that under 11 ounces or 312 g of continuous force and 160 lbs of shear force the inserted implant was able to achieve absolute anchorage to move a tooth toward it.[33] Creekmore and Eklund was reached.[14] In the study, a TAD was inserted just below the anterior nasal spine for incisor intrusion. After superimposing the pretreatment and posttreatment cephalometric radiographs, they found the TAD was immobile during treatment.[14] Yet, they postulated that without an adequate biological rationale, adequate understanding of the reliability, stability, rejection, infection, or other pathology, its clinical application is premature.[14] The 1990s explored experimental biomechanical studies, animal testing and clinical investigations to determine that dental implants when placed in alveolar bone can be unaffected by applied orthodontic forces. TADs were later found to be beneficial in the correction of deep bites during orthodontic

treatment.[34-38] In 1995, a 2-stage hydroxylapatite-coated titanium subperiosteal implant (Onplant, Nobel Biocare, Göteburg, Sweden) was developed.[14,39] This system has several characteristics: disc shaped, 10 mm in diameter, 2 mm thick, coated with hydroxylapatite on the side against bone, and smooth titanium facing soft tissue with a threaded hole where abutments will be placed.[39] Onplants have been shown, in animal models, to provide sufficient anchorage to move and anchor teeth.[14] A study by Sugawara et al. in 2004 introduced titanium anchorage plates and monocortical screws as a skeletal anchorage system (SAS) in both the maxilla and mandible to function as an absolute anchorage unit distalizing molars in adults.[40] Prior to the technique, the distalization of molars could be considered a difficult and time-consuming movement. The use of the anchorage in orthodontics has always been an integral role when utilizing the biomechanics necessary to accomplish tooth movement. The clinical success of TAD use became a reality and allowed clinicians looking for additional modalities to execute biomechanics more effectively.

Design

TADs are composed of 3 parts: the head, the neck, and the screw. The head is the exposed portion of the TAD that provides attachment for springs,

elastics, wires and other orthodontic armamentarium. Depending on the anchorage needed, the design of the head can be a sphere, double sphere, or hexagonal shaped. The neck, also considered the transmucosal part of the TAD. The neck comes in various sizes to accommodate mucosal thickness. In addition, it should be smooth and well-polished to prevent plaque aggregation as implant failure usually stems from peri-implantitis at this location. The neck connects the head to the screw portion of the TAD. The screw is fixed in the bone utilizing the cortical bone for retention. The threads of the screw allow for the insertion of the TAD and mechanical retention of the device. The retention provides the rigidity needed for the stress generated as the biomechanical forces are applied to the TAD. When considering the length of the TAD, the length of the screw portion is the determining variable. The length can be 5 to 12 mm, totaling the distance from the head to the screw.[41] In 2013 Petrey et al, showed the retention of TADs increased with the length of the TAD.[42] Yet, Costa et al. found that TAD lengths of 4 to 6 mm are safe in most regions when looking at hard and soft tissue parameters.[43] The diameter of the TAD consists of the outer distance of the threads in screw with a range of 1.2 to 2 mm. In an article by Lui et. al,TADs with a diameter of more than 2 mm should not be in the inter-radicular area and there is a risk of breakage when using less than 1.2 mm.[44] The minor diameter is the inner core diameter of the screw ranging from 0.2 to 1.6mm. Lastly, the pitch of the screw is the distance between two vertical threads. If

the threads are far apart then the TAD is considered high pitch and if they are closer they are considered low pitch.[41]

TAD Properties

The properties of TADs are biocompatibility, osseointegration, and types of anchorage.[45] Medical grade titanium is considered the gold standard when considering biocompatibility and strength. Medical type IV or type V titanium alloy (Ti6Al4V), an alloy of aluminum, titanium and vanadium, is the composition of choice in the majority of implants, excluding orthodontic mini implants, which uses stainless steel. The retention of TADs derives from its mechanical interaction with bone. Yet, in a systematic review by Mecenas et al in 2020, they found that “the material used is not a major factor in the success rate of mini-implants.” in addition, the major difference in selection of material was due to the lower price stainless provides while allowing for similar clinical efficiency to titanium. Mecenas 2020 [46] To reduce difficulty removing the TADs, they are designed with smooth surfaces to inhibit substantial osseointegration and still allow for ample anchorage.[41]

Applications

Indications for TAD use. As the orthodontic application of TADs has continued to be studied, its indications in a clinical setting have increased to become a viable clinical tool for orthodontists to utilize. The ability for TADs to achieve absolute or infinite anchorage, defined as no movement of the anchorage unit as a consequence of the reaction forces applied to move teeth, allows for retraction and protraction movements.[41,47] TADs can be beneficial to non-compliant patients where orthognathic intervention is needed during the growth phase as a replacement for headgear.[41] Protraction and distalization of teeth in cases of congenitally missing teeth or loss of a permanent tooth would also benefit from the use of TADs. Additionally, more complex movements can also be accomplished such as anterior/posterior intrusion, en masse distalization of the upper/lower arches, molar uprighting and molar distalization, and midline correction.[41] Furthermore, correction depp bite, closure of extraction spaces, correcting occlusal cants, aligning impact canines, intrusion of molars, and correction of vertical discrepancies can all be impacted by the use of orthodontic TADs.[41] TADs can also be used for intrusion of molars.

Space closure/retraction. Barthelemi et al, in 2020, evaluated the efficiency of anchorage provided by temporary anchorage devices (TADs) in maxillary bicuspid extraction cases during retraction of the anterior teeth using a fixed appliance. When looking at 31 patients aged 12 to 50 years with malocclusion for which bilateral first or second maxillary bicuspid extractions

and randomly allocated to the TAD or control groups. The two groups showed a significant difference in the movement of the first maxillary molars, with less significant anchorage loss in the TAD group than that in the control group. In addition, TAD movement showed only a slight mesial movement on the labial side. On the palatal side, the mesial TAD movement was greater. In comparison with conventional dental anchorage, TADs can be considered an efficient source of anchorage during retraction of maxillary anterior teeth. TADs remain stable when correctly placed in the bone during the anterior tooth retraction phase.[48]

MARPE. In 2019, Shin et al. looked at miniscrew-assisted rapid palatal expansion (MARPE) used in patients with maxillary constriction. Although previous studies have reported that the success rates of MARPE in adults range from 84.2% to 86.96% and MARPEs often shows adverse effects such as buccal tipping or bony dehiscence of the posterior teeth, the study found that age, palate length, and MPSM (midpalatal suture maturation) stage can be predictors of midpalatal suture expansion by MARPE in young adults.[49]

Intrusion. In 2007 Moon et al achieved 3.0 mm of intrusion in the first molar and 3.5 mm intrusion in the second molar during a 2 month treatment period by corticotomy and orthodontic skeletal anchorage with a miniplate and TADs.[50] The study found the result to be maintained 11 months post treatment.[50]

Protraction. Karvitz and Jolley observed molar protraction in the mandible in their 2008 citing, “protraction of mandibular molars is challenging because of the high density of mandibular bone.. Furthermore, if the buccal and lingual cortical plates in the edentulous region have collapsed, safe and effective protraction may be impossible.” They found that by placing a miniscrew anterior to the endentulous space and the intended molar to be protracted, and using a lingual elastic thread tied to the archwire or banding the molar to be protracted and placing it on a lingual arch for sliding can be used to provide balancing lingual force. In addition a “push pull” technique can also be used where there is an edentulous space mesial to the second premolar, and the miniscrew is placed in the edentulous space and used to pull the first molar mesial and an open coil spring pushes the second premolar mesial.[51]

Anterior incisor intrusion to correct deep bite. Gomaa et al evaluated changes of smile and gingival line after intrusion of maxillary incisors using mini-implant anchorage system or conventional accentuated compensating curve archwire. The study found that there was an improvement of smile arc (consonance) from 30% smile consonance pretreatment to 90% consonance postintrusion, a significant decrease in the upper lip to upper incisal edge relationship, and a significant decrease in overbite when compared to a group using conventional accentuated compensating curve archwire. [52]

Open bite. Miniscrews can also be used to correct anterior open bites as Park et al reported in 2008. They found that the application of orthodontic miniscrews has simplified the treatment of an anterior open bite by making it more efficient and esthetic. A 19-year-old woman with an anterior open bite was treated by an intrusion of the maxillary posterior teeth using miniscrews. The posterior teeth were splinted on the palatal side with rapid maxillary expansion (RME), and an intrusive force was then applied to the miniscrews on the buccal side. The 3.5 mm anterior open bite was corrected after 5 months of intrusion. As a result, a harmonious facial profile was achieved by a closing mandibular rotation. [53]

Patient selection

As with all orthodontic patients, selection plays an important role in determining the success of the treatment plan. Understanding the patient's goals, limitations, expectations and communicating the treatment plan can all lend itself to patient acceptance of treatment. This is even more true when considering TADs for a patient's treatment plan. Proper case selection, informed consent and records should be taken. As well as, patient medical history and assessment of oral cavity for absence of gingival inflammation and periodontal disease are to be done initially. Informed consent should always be obtained from the patient or the parent. Apart from the usual

orthodontic records, intraoral radiographs of the proposed miniscrew site have to be taken to assess the bone morphology and roots of adjacent teeth.[10,18] If a more thorough understanding of the bone density and position of the teeth or other anatomical features are needed a Cone Beam Computed Tomography (CBCT) will be indicated. It has been suggested that D4 and D5 bones types are not suitable for implants.[41, 54]

Anatomical site of insertion

TADs can be placed in the maxilla and mandible for orthodontic anchorage. The maxillary regions include incisive fossa, canine fossa, infra-zygomatic ridge, pre-maxillary region or mid-palatal region. The mandibular regions are symphysis, canine fossa, anterior external oblique ridge, retro-molar area or sub-maxillary fossa.[43] Although there are many locations to consider when placing TADs studies have concluded that the safest sites in the maxilla are the the anterior and apical portion and the tuberosity region was most unsuited for implant placement due to reduced bone thickness in this region. The safest region in the mandible is between the first and second premolars.[55] Bernhart and Vollgruber found the strong bone support in the palate to be 6 to 9 mm posterior to the incisive foramen and 3 to 6 mm paramedian.[56] It was also concluded that placing the TAD in the extra alveolar

bone allows the force vector to be closer to the center on resistance of the tooth and diminishes contact with the tooth's root.[43]

Bone thickness has also been shown to be important when placing TADs. Deguchi et al quantitatively assess cortical bone thickness in various locations in the maxilla and the mandible as well as the distances from intercortical bone surface to root surface, and distances between the roots of premolars and molars to determine the acceptable length and diameter of the miniscrew for anchorage during orthodontic treatment.[57] Their evaluation used three-dimensional computed tomographic images to measure the Cortical bone thicknesses of the buccal and lingual regions mesial and distal to the first molar, distal to the second molar, and in the premaxillary region.[57] The data showed that the safest location for placing miniscrews might be mesial or distal to the first molar, and an acceptable size of the miniscrew is less than approximately 1.5 mm in diameter and approximately 6 to 8 mm in length.[57]

Anterior palate. In 2015, Poortsattar-Bejeh Mir et al. looked at site insertion of a miniscrew in a hard palate and useda scoring system to select optimal sites. The study consisted of 37 adult patients (21 females and 16 males) aged between 20 and 50 years, with a mean age of 34.81 (±9.52) years. They found significant variability was found between the individuals: Total vertical bone height decreased posteriorly and laterally, Mucosal thickness decreased posteriorly, but increased laterally, and Palatal cortical

thicknesses were higher than the nasal cortical thicknesses. Yet, The most balanced sites (highest point) were the midpalatal suture, followed by paramedian points located 3 mm lateral to the midline and 4 mm posterior to the incisive canal.[58]

Buccal shelf Elshebiny et al, in 2018, assessed the best placement for miniscrews in the buccal shelf in white patients. After observing 30 patients, the study determined that insertion site and measurement level has significant impacts on both cortical bone thickness and bone width. Therefore, distobuccal cusp level of the mandibular second molar is the most appropriate site for miniscrew insertion at the buccal shelf in white patients.[59]

Infrazyogomatic Chang et al. looked at the 6-month survival (success) rate for infrazyogomatic crest (IZC) bone screws relative to patient age, insertion angle, sinus penetration, and terminal insertion torque. One hundred consecutive patients (27 males, 73 females; mean age 25.8 years; age range, 11.0-53.8 years) received IZC temporary anchorage devices (TADs) bilaterally. Each TAD was routinely loaded with up to 14 oz (397 g or 389 cN), reactivated monthly, and followed for 6 months. Both sinus perforation and IZC bone quality increased with age. Sinus penetration did not significantly affect the 6 month survival rate of IZC TADs because the loss of bone

quantity at the interface was offset by the age-related increase in bone quality at the IZC site.[60]

Posterior palate When considering maxillary expansion, a Maxillary Skeletal Expander (MSE), which is a particular design of a MARPE that uses four palatal miniscrews, has been shown to be a viable option. Identifying ideal insertion sites are important to the success of the device. Cantarella et al achieved a 90% posterior nasal spine parallel split of the anterior nasal spine split when using four mini-implants positioned in the posterior part of the palate with bi-cortical engagement. Of the fifteen subjects used with an average age of 17.2 years there were no significant differences found in the magnitude and frequency of suture opening between males and females.[61]

Palatal alveolar process In 2020 Yu explained, “when placing a TAD in the palatal alveolar process area they should be placed in the safest anatomical position, and consideration given to cortical bone and soft tissue thick-ness, root proximity, and anatomical limitations so as to reduce the likelihood of failure.” Palatal alveolar bone is a good site for TAD insertion and can be used effectively in lingual orthodontics and molar intrusion. Palatal soft tissue thick-ness increased gradually from the CEJ toward the apical region and palatal cortical bone thickness was greatest 6 mm apical to the CEJ. Palatal cortical bone is thicker and denser than buccal cortical bone. The

thickest palatal cortical bone was found between the canine and first premolar, and the densest interradicular palatal bone was between the first and second premolars. With regard to available space, the palatal interradicular space was widest between the first and second molars. The neurovascular bundle (greater palatine artery, greater palatine nerve) was reported to be 7–17 mm from the maxillary posterior palatal CEJ, depending on the shape of the palatal vault and it reportedly runs for an average distance of 12 mm.The risk of root damage is less on the palatal side than on the buccal side due to abundant interradicular space. The placement sites on the palatal side are typically wider than those on the buccal side if damage to the neurovascular bundle can be avoided. It is recommended to place longer TADs on the palatal side because the soft tissue is thicker there than on the buccal side. When planning the insertion the safety margin in the radiographic images for palatal TAD insertion is vertically (perpendicular to the occlusal plane) 9 mm from the gingival margin, while the clinical safety margin along the palatal slope would be approximately 11 mm.[62]

Placement technique

TADs can be placed by self-drilling or self-tapping techniques. CBCT and stereolithographic techniques have been used to fabricate 3D printed surgical guides to assist in the placement of the miniscrews. This guide aids

the placement of self-drilling miniscrews allowing for precision placement when close to roots and integral anatomical structures. [63,64] Using a CBCT system, Kim et al. was able to create virtually reproduced replicas of the posterior maxilla that were 0.1 to 0.15 mm thick, and provide a surgical guide enabling precise pilot drilling and accurate placement of the mini-implant. [64]

When using self-tapping screws local anesthesia can be preferable. Soft tissue is removed at the placement site using a soft tissue punch. A pilot hole is created and a drill bit is used to make a hole at no more than 1000rpm. The pilot hole should be 2 to 3 mm in depth and 0.3 mm smaller in diameter to the miniscrew. The mini screw or implant is then screwed in using the appropriate screw driver.[41]

The self-drilling screws are designed tip and cutting flutes where predrilling into the bone is not required. This can reduce the likelihood of damaging the tooth root, tooth germ or nerves, thermal necrosis of the bones and fracture of the drill bit.[65] If the thickness of the cortical bone was 2 mm thick then a pilot hole should be used to prevent bending of the fine tip of the screw.[45]

Although local anesthesia can be used for patient comfort when placing TADs. In a 2006 study Kravitz et al discussed the placement of mini-implants using topical anesthetic as being easily administered by the clinician and being comfortable for the patient.[66] In addition topical anesthetic diffuses

through 2-3 mm of the mucous membrane so there is no pulpal anesthesia, and no gingival ballooning occurs as in local anesthetics.[66]

Loading forces

Unlike traditional dental implants immediate loading forces can be applied to orthodontic miniscrews using light forces.[67] Liou et al. recommends 2mm of space between the implant and adjacent teeth when placing a TAD due to possible movement during insertion and TAD movement on loading in some patients.[68] In a study conducted by Wang and Liou, it was concluded that loading behaviors of predrilled and self-drilling miniscrews (2 mm in diameter and 10 to 17 mm long) were similar in the infrazygomatic crest of the maxilla when analyzing pretreatment and post treatment cephalometric tracings.[69] Although the miniscrews remained stable, without detectable mobility or loosening, throughout the treatment period, miniscrews were all significantly displaced in accordance with the force direction of the nickel-titanium coil springs. The displacements were 0.0 to 1.6 mm with extrusion, 1.5 mm with forward or backward tipping at the screw tail, and 1.5 mm with forward tipping at the screw head.[69]

Implant removal

The TAD can be removed using the same screwdriver with or without anesthesia depending on the patient's and dentist's comfort level. The injured tissue does not require additional attention when healing. If the screw cannot be removed during the initial attempt it is recommended to wait 3 to 4 days before attempting again as the microfractures in the bone caused during the initial attempt will loosen the screw and allow for easier retrieval.[41] If there is a screw fracture during removal a small surgical procedure will be required to remove the screw.[45]

Risk/complications

Successful anchorage is dependent on the placement of the TAD. But just as importantly the clinical success depends on the patient's oral hygiene and care of the appliance while in place. In a study by Park et al. the success rate and factors affecting the clinical success of screw implants using orthodontic anchorage was minimized when inflammation around the implant was controlled. The study found that although the overall success rate was 91.6% the rate of failures increased when the screw implants were placed on the right side of the mandible.[70]

Placement torque is also an important factor during TAD insertion. In a 2006 study by Motoyoshi et al, adequate placement torque for obtaining a better success rate of mini-implants that are screwed into the buccal alveolar bone of the

posterior region as an anchor for orthodontic treatment was investigated and, implant placement torque (IPT) was measured.[71] The study looked at 41 orthodontic patients with an average age of 24.9 years where 124 implants were placed in total. The success rate of the implants was 85.5% and the mean IPT ranged from 7.2 to 13.5 N/cm depending on the location of the implants.[71] The IPT in the mandible was, unexpectedly, significantly higher in the failure group than in the success group. Therefore, a large IPT should not be used always. According to our calculations of the risk ratio for failure, to raise the success rate of 1.6-mm diameter mini-implants, the recommended IPT is within the range from 5 to 10 N/cm.[71]

Insertion location in relation to root proximity can play a large role in TAD success. In 2007, Kuroda et al looked at the root proximity during TAD placement as a risk factor for the failure of miniscrews used as orthodontic anchorage.[72] The study established placement of the TAD in relation to the tooth as follows: Category I, the screw was absolutely separate from the root; category II, the apex of the screw appeared to touch the lamina dura; and category III, the body of the screw was overlaid on the lamina dura. Screws where there orthodontic force could be applied for 1 year were recorded as a success. The study found the screws had a success rate above 80%. Yet, screws placed in the maxilla had a significantly higher success rate than those in the mandible. In addition, screws in all 3 categories in the maxilla and categories I and II in the mandible showed high success rates above 75%, screws in category III in the mandible had a low success rate of 35%.[72]

Placement time is also an important factor when looking at the potential success of TADs. A study by Tseng et al in 2006 explored the use of mini-implants for skeletal anchorage, and to assess their stability and the causes of failure.[73] A total of 45 mini-implants were used in orthodontic treatment with a 2 mm diameter and lengths of 8, 10, 12, 14 mm. The TADs were placed through the cortical bone without flap. After 2 weeks a force of 100-200g was applied by an elastometric chain or NiTi coil spring. The overall success rate was 91.1% with 4 implants loosening after orthodontic force loading.[73]

Direct anchorage and indirect anchorage are the two types of anchorage when establishing treatment mechanics with TADs. When the force is applied directly to the TAD, direct anchorage occurs, and when bars or wire are attached to the TAD, indirect anchorage results. The anchorage of TADs permits up to 500g of force; whereas; up to 300g of force is required for normal orthodontic mechanics.[41] Due to a study indicating that direct loading may cause overloading of the TAD and thereby lead to failure, indirect anchorage may be a more suitable treatment option when clinically achievable.[74,75]

Clinical adoption

The increased functions and understanding the additive applications of TADs has made them a more desirable feature when treatment planning. Yet,

there can be hurdles to clinical adaptations, such as the comfort level of the patient and orthodontist, and the use of local anesthesia due to the TAD being placed in the oral cavity through the gingiva and bone of the patient. In a 2008 study by Cornelis et al patients' and orthodontists' perceptions of miniplate used for temporary skeletal anchorage was investigated.[39] 72% of patients did not mind having the miniplates after a year in place and 82% the surgical experience was better than expected with little to no pain.[39] From the 200 miniplates placed in 97 patients there was a success rate of 92.5%. The study concluded that miniplates are well accepted by patients and providers and are a safe and effective adjunct for complex orthodontic treatments.[39] Although research shows promising data the appreciation and proper training of TADs can maximize clinical success and patient satisfaction.

In 2009, research was conducted to determine the use of TADs in private practice and orthodontic residency programs. The study found that 82.9% of orthodontic residency programs and 69.2% of orthodontists placed TADs. In orthodontic programs 61.9% and 79% of orthodontic practitioners immediately loaded the TADs typically for retraction. Since 2005 there has been a push to increase the use of TADs in residency, didactic and research curriculums (Shirck et al, 2011)[76]. A 2014 study distributed a survey to Swiss orthodontists concluded distalization against palatal implants was the most popular treatment plan and the placement varied on the type and size of the TAD, but even more greatly in the sagittal versus the transversal dimension.[77]

In 2020, Baumgaertel et al. determined that palatal miniscrews were more successful than buccal miniscrews and indirect anchorage mechanics had a higher success rate than direct anchorage mechanics when examining the success rates of miniscrews placed by orthodontic residents. The overall success rate for miniscrews was 72.5%. The success rate was 83.9% in the anterior palate, 76% in the palatal alveolar process, 60% in the maxillary buccal alveolar process, and 65.8% in the mandibular buccal alveolar process. The success rate was significantly higher in indirect anchorage (84.2%) compared with direct anchorage (58.8%).[78]

In a 2020 longitudinal study, Keim et al. found that molar protraction was most commonly used, more than 40% of participants used TADs for open bite, molar intrusion, Class II treatment, molar distalization, correction of occlusal-plane cant, or anterior intrusion. The study also concluded that TAD use in practices fell to 55%, from 70% in 2014 and 61% in 2008. The data continued to show that from 2014 to 2020 cases using TADs dropped from 8 to 5, respectively. Yet, an increase from 35% to 46% of participants found TADs to decrease the number of surgical cases treated.[79]

Although there have been numerous articles showing the impact and effectiveness of TADs in orthodontic treatment as viable tools for absolute anchorage it is still unclear how many orthodontists in the United States currently understand these benefits. A detailed understanding of the factors influencing clinical adoption can help increase its appreciation and practical

use in a clinical setting, improving efficiency and efficacy in orthodontic treatment in the United States.

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STATEMENT OF THESIS

Objective: The purpose of this study is to evaluate the current use of TADs in the United States, determine what factors influence the adoption of TADs, discover the demographics of the orthodontists placing TADs, and determine how TADs are used in practice.

Hypothesis: TAD use by orthodontists is decreasing, there are factors that influence TAD adoption in postgraduate settings, orthodontists that have been practicing for 30+ years are less likely to use TADs, and TADs are most commonly used for expansion.

MANUSCRIPT FOR PUBLICATION

A Comprehensive Survey on the Use of Temporary Anchorage Devices in Orthodontics in the United States

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Abstract

Introduction

The purpose of this study is to discover the demographics of the orthodontists placing TADs, evaluate the current use of TADs in the United States, determine what factors influence the adoption of TADs, and determine how TADs are used in practice.

Methods

A pilot survey was created using REDcap® software through Case Western Reserve University and distributed to 10 practicing orthodontists in the US. Using the feedback a 29 question survey was recreated to better gather data for analysis. Once the survey was finalized then a duplicate survey for a test retest reliability survey. The test retest reliability survey was distributed to 10 participants, and then retaken 3 weeks following their initial survey submission. The test retest reliability results will detail the stability of the scores across time. Simultaneously, the primary 29 question survey was distributed to practicing orthodontists in the United States via Facebook, Instagram, mail, and at AAO regional conferences. The distribution material contained directions to access the enclosed survey link or QR code. Once the

survey distribution was completed, the data was analyzed for correlations and causality using SPSS statistical software.

Results

Of the 245 total viable surveys taken from the data sample 57.1% use TADs, 24.1% previously used TADs, 23.3% never used TADs. In addition, 20.4% have been in practice for 1-5 years,19.6% have been in practice for 6-10 years, and 15.5% have been in practice for 30+ years. Of those that use TADs 65.9% received their training in TAD placement in a postgraduate setting. Of those that use TADs 44.2% have used TADs for maxillary posterior intrusion, 41.1% have used MARPE in their office.

Conclusion

Current TAD use by practitioners in the United States is popular with 57.1% of orthodontists using TADs in practice and 49.1% have an increased interest in continuing to use them at the same or higher rate over the next 5 years. When assessing factors that influence clinical adoption, most orthodontists placing TADs received their training in a postgraduate setting (65.9%) and 66% placed at least 1 TAD in their post residency career. The most common group of orthodontists using TADs had 1 to 5 years practice

and were owners/partners (20.4% and 62.7%, respectively). TADs have various uses to assist in achieving treatment planning goals. Maxillary expansion is the second most common way in which people use TADs (44.2%) behind maxillary posterior intrusion (41.1%). Fixed appliances in combination with TADs was the most common combination modality selected (66.7%).

Throughout time the use of screws has evolved for application in medicine and eventually orthodontics as TADs (Temporary Anchorage Devices). Fixation in orthopedics was first published in a French manuscript in 1775,where an iron wire was used for fixation of a bone fracture.[1] Throughout the 18th and 19th centuries the most common fixation technique was the use of cerclage wires to fix fractures.[1] Internal fixation was not a practical method of use due to the safety and high risk of sepsis. It was not until Lister, the father of asepsis, ensured the safety of open reduction and internal fixation making it possible to directly treat fractures in his 1867 publication.[1] In 1877, Lister successfully treated a patellar fracture using his antiseptic method to evenly fixate closed fractures using metal wires.[1,2,3] The technique was revolutionary and opened the possibilities of how fixation can be applied to other aspects of medicine. The use of fixation in traditional medicine eventually led to its fascination and potential in collaboration with orthodontic tooth movement and anchorage.

Orthodontic anchorage was first clearly defined in 1923 by Louis Ottofy as “The base against which orthodontic force or reaction of orthodontic force is applied.”[4,5] Outlined categories of anchorage by E.H. Angle and others were summarized by Ottofy as simple, stationary, reciprocal, intraoral, intermaxillary, or extraoral.[5] Moyer expounded on Ottofy’s definition by

outlining subcategories of extraoral anchorage. Yet, orthodontic anchorage still had limitations.

As with any field of study, the accomplishments within that field are beholden to the technology, tools, and skill of the practitioner of that time. When looking back at our orthodontic predecessors their clinical achievements were based on and coincided with where the technology was at that time and what tools of that time could support. Fauchard in 1728 described an expansion arch which broadened the crowded dentition to a more normal form by using an ideal arch shaped metal plate attached to the teeth.[6] Occipital anchorage was professed by Gunnell in 1822 but details of the achievement were not detailed until 1841 and later refined by E.H. Angle in 1891.Weinberger BW1926[7] In 1841, J.M.A. Schange improved on Christophe-Francois Delabarre's 1819 original design for the crib of Delabarre, which was attached to the palatal plate for anchorage and allowed for a labial arch and ligatures of silk or gold wires to achieve various tooth movements.[4,7] In addition to Angle's refinement of the occipital anchorage he also established the concept of stationary anchorage in 1887 and occlusal anchorage in 1891.[4,7]

As the orthodontic application of TADs has continued to be studied, its indications in a clinical setting have increased to become a viable clinical tool for orthodontists to utilize. The ability for TADs to achieve absolute or infinite anchorage, defined as no movement of the anchorage unit as a consequence

of the reaction forces applied to move teeth, allows for retraction and protraction movements.[8,9] TADs can be beneficial to non-compliant patients where orthognathic intervention is needed during the growth phase as a replacement for headgear.[8] Protraction and distalization of teeth in cases of congenitally missing teeth or loss of a permanent tooth would also benefit from the use of TADs. Additionally, more complex movements can also be accomplished such as anterior/posterior intrusion, en masse distalization of the upper/lower arches, molar uprighting and molar distalization, and midline correction.[10] Furthermore, correction deep bite, closure of extraction spaces, correcting occlusal cants, aligning impact canines, intrusion of molars, and correction of vertical discrepancies can all be impacted by the use of orthodontic TADs.[8] TADs can also be used for intrusion of molars. Space closure and retraction, the use of MARPEs, intrusion protraction, and correction of deep and open bite have all been applications where TADs have been used to achieve treatment goals.

In 2007 Moon et al achieved 3.0 mm of intrusion in the first molar and 3.5 mm intrusion in the second molar during a 2 month treatment period by corticotomy and orthodontic skeletal anchorage with a miniplate and TADs.[10] The study found the result to be maintained 11 months post treatment.[10]

Karvitz and Jolley observed molar protraction in the mandible in their 2008 citing, “protraction of mandibular molars is challenging because of the high density of mandibular bone.. Furthermore, if the buccal and lingual

cortical plates in the edentulous region have collapsed, safe and effective protraction may be impossible." They found that by placing a miniscrew anterior to the endentulous space and the intended molar to be protracted, and using a lingual elastic thread tied to the archwire or banding the molar to be protracted and placing it on a lingual arch for sliding can be used to provide balancing lingual force. In addition a "push pull" technique can also be used where there is an edentulous space mesial to the second premolar, and the miniscrew is placed in the edentulous space and used to pull the first molar mesial and an open coil spring pushes the second premolar mesial.[11]

Gomaa et al evaluated changes of smile and gingival line after intrusion of maxillary incisors using mini-implant anchorage system or conventional accentuated compensating curve archwire. The study found that there was an improvement of smile arc (consonance) from 30% smile consonance pretreatment to 90% consonance post intrusion, a significant decrease in the upper lip to upper incisal edge relationship, and a significant decrease in overbite when compared to a group using conventional accentuated compensating curve archwire.[12]

Miniscrews can also be used to correct anterior open bites as Park et al reported in 2008. They found that the application of orthodontic miniscrews has simplified the treatment of an anterior open bite by making it more efficient and esthetic. A 19-year-old woman with an anterior open bite was treated by an intrusion of the maxillary posterior teeth using miniscrews. The posterior teeth were splinted on the palatal side with rapid maxillary

expansion (RME), and an intrusive force was then applied to the miniscrews on the buccal side. The 3.5 mm anterior open bite was corrected after 5 months of intrusion. As a result, a harmonious facial profile was achieved by a closing mandibular rotation.[13]

TADs can be placed in the maxilla and mandible for orthodontic anchorage. The maxillary regions include incisive fossa, canine fossa, infra-zygomatic ridge, pre-maxillary region or mid-palatal region. The mandibular regions are symphysis, canine fossa, anterior external oblique ridge, retro-molar area or sub-maxillary fossa.[14] Although there are many locations to consider when placing TADs studies have concluded that the safest sites in the maxilla are the anterior and apical portion and the tuberosity region was most unsuited for implant placement due to reduced bone thickness in this region. The safest region in the mandible is between the first and second premolars.[15] Bernhart and Vollgruber found the strong bone support in the palate to be 6 to 9 mm posterior to the incisive foramen and 3 to 6 mm paramedian.[16] It was also concluded that placing the TAD in the extra alveolar bone allows the force vector to be closer to the center on resistance of the tooth and diminishes contact with the tooth's root.[14]

In 2015, Poortsattar-Bejeh Mir et al. looked at site insertion of a miniscrew in a hard palate and used a scoring system to select optimal sites. The study consisted of 37 adult patients (21 females and 16 males) aged between 20 and 50 years, with a mean age of 34.81 (±9.52) years. They

found significant variability was found between the individuals: Total vertical bone height decreased posteriorly and laterally, Mucosal thickness decreased posteriorly, but increased laterally, and Palatal cortical thicknesses were higher than the nasal cortical thicknesses. Yet, The most balanced sites (highest point) were the midpalatal suture, followed by paramedian points located 3 mm lateral to the midline and 4 mm posterior to the incisive canal.[17]

In 2019, Shin et al. looked at mini-screw-assisted rapid palatal expansion (MARPE) used in patients with maxillary constriction. Although previous studies have reported that the success rates of MARPE in adults range from 84.2% to 86.96% and MARPEs often shows adverse effects such as buccal tipping or bony dehiscence of the posterior teeth, the study found that age, palate length, and MPSM (midpalatal suture maturation) stage can be predictors of midpalatal suture expansion by MARPE in young adults.[18]

Elshebiny et al, in 2018, assessed the best placement for miniscrews in the buccal shelf in white patients. After observing 30 patients, the study determined that insertion site and measurement level has significant impacts on both cortical bone thickness and bone width. Therefore, distobuccal cusp level of the mandibular second molar is the most appropriate site for miniscrew insertion at the buccal shelf in white patients.[19]

Looking at space closure, Barthelemi et al, in 2020, evaluated the efficiency of anchorage provided by temporary anchorage devices (TADs) in maxillary bicuspid extraction cases during retraction of the anterior teeth

using a fixed appliance. When looking at 31 patients aged 12 to 50 years with malocclusion for which bilateral first or second maxillary bicuspid extractions and randomly allocated to the TAD or control groups. The two groups showed a significant difference in the movement of the first maxillary molars, with less significant anchorage loss in the TAD group than that in the control group. In addition, TAD movement showed only a slight mesial movement on the labial side. On the palatal side, the mesial TAD movement was greater. In comparison with conventional dental anchorage, TADs can be considered an efficient source of anchorage during retraction of maxillary anterior teeth. TADs remain stable when correctly placed in the bone during the anterior tooth retraction phase.[20]

Chang et al. looked at the the 6-month survival (success) rate for infrazygomatic crest (IZC) bone screws relative to patient age, insertion angle, sinus penetration, and terminal insertion torque. One hundred consecutive patients (27 males, 73 females; mean age 25.8 years; age range, 11.0-53.8 years) received IZC temporary anchorage devices (TADs) bilaterally. Each TAD was routinely loaded with up to 14 oz (397 g or 389 cN), reactivated monthly, and followed for 6 months. Both sinus perforation and IZC bone quality increased with age. Sinus penetration did not significantly affect the 6 month survival rate of IZC TADs because the loss of bone quantity at the interface was offset by the age-related increase in bone quality at the IZC site.[22]

When considering maxillary expansion, a Maxillary Skeletal Expander (MSE), which is a particular design of a MARPE that uses four palatal miniscrews, has been shown to be a viable option. Identifying ideal insertion sites are important to the success of the device. Cantarella et al achieved a 90% posterior nasal spine parallel split of the anterior nasal spine split when using four mini-implants positioned in the posterior part of the palate with bi-cortical engagement. Of the fifteen subjects used with an average age of 17.2 years there were no significant differences found in the magnitude and frequency of suture opening between males and females.[23]

In 2020 Yu explained, “when placing a TAD in the palatal alveolar process area they should be placed in the safest anatomical position, and consideration given to cortical bone and soft tissue thick-ness, root proximity, and anatomical limitations so as to reduce the likelihood of failure.” Palatal alveolar bone is a good site for TAD insertion and can be used effectively in lingual orthodontics and molar intrusion. Palatal soft tissue thick-ness increased gradually from the CEJ toward the apical region and palatal cortical bone thickness was greatest 6 mm apical to the CEJ. Palatal cortical bone is thicker and denser than buccal cortical bone. The thickest palatal cortical bone was found between the canine and first premolar, and the densest interradicular palatal bone was between the first and second premolars. With regard to available space, the palatal interradicular space was widest between the first and second molars. The neurovascular bundle (greater

palatine artery, greater palatine nerve) was reported to be 7–17 mm from the maxillary posterior palatal CEJ, depending on the shape of the palatal vault and it reportedly runs for an average distance of 12 mm. The risk of root damage is less on the palatal side than on the buccal side due to abundant interradicular space. The placement sites on the palatal side are typically wider than those on the buccal side if damage to the neurovascular bundle can be avoided. It is recommended to place longer TADs on the palatal side because the soft tissue is thicker there than on the buccal side. When planning the insertion the safety margin in the radiographic images for palatal TAD insertion is vertically (perpendicular to the occlusal plane) 9 mm from the gingival margin, while the clinical safety margin along the palatal slope would be approximately 11 mm.[24]

Successful anchorage is dependent on the placement of the TAD. But just as importantly the clinical success depends on the patient's oral hygiene and care of the appliance while in place. In a study by Park et al. the success rate and factors affecting the clinical success of screw implants using orthodontic anchorage was minimized when inflammation around the implant was controlled. The study found that although the overall success rate was 91.6% the rate of failures increased when the screw implants were placed on the right side of the mandible.[25]

Bone thickness has also been shown to be important when placing TADs. Deguchi et al quantitatively assess cortical bone thickness in various

locations in the maxilla and the mandible as well as the distances from intercortical bone surface to root surface, and distances between the roots of premolars and molars to determine the acceptable length and diameter of the miniscrew for anchorage during orthodontic treatment.[26] Their evaluation used three-dimensional computed tomographic images to measure the Cortical bone thicknesses of the buccal and lingual regions mesial and distal to the first molar, distal to the second molar, and in the premaxillary region.[26] The data showed that the safest location for placing miniscrews might be mesial or distal to the first molar, and an acceptable size of the miniscrew is less than approximately 1.5 mm in diameter and approximately 6 to 8 mm in length.[26]

Placement torque is also an important factor during TAD insertion. In a 2006 study by Motoyoshi et al, adequate placement torque for obtaining a better success rate of mini-implants that are screwed into the buccal alveolar bone of the posterior region as an anchor for orthodontic treatment was investigated and, implant placement torque (IPT) was measured.[27] The study looked at 41 orthodontic patients with an average age of 24.9 years where 124 implants were placed in total. The success rate of the implants was 85.5% and the mean IPT ranged from 7.2 to 13.5 N/cm depending on the location of the implants.[27] The IPT in the mandible was, unexpectedly, significantly higher in the failure group than in the success group.[27] Therefore, a large IPT should not be used always. According to our calculations of the risk ratio for failure, to raise the success rate of 1.6-mm diameter mini-implants, the recommended IPT is within the range from 5 to 10 N/cm.[27]

Insertion location in relation to root proximity can play a large role in TAD success. In 2007, Kuroda et al looked at the root proximity during TAD placement as a risk factor for the failure of miniscrews used as orthodontic anchorage.[28] The study established placement of the TAD in relation to the tooth as follows: Category I, the screw was absolutely separate from the root; category II, the apex of the screw appeared to touch the lamina dura; and category III, the body of the screw was overlaid on the lamina dura. Screws where there orthodontic force could be applied for 1 year were recorded as a success. The study found the screws had a success rate above 80%. Yet, screws placed in the maxilla had a significantly higher success rate than those in the mandible. In addition, screws in all 3 categories in the maxilla and categories I and II in the mandible showed high success rates above 75%, screws in category III in the mandible had a low success rate of 35%.[28]

Placement time is also an important factor when looking at the potential success of TADs. A study by Tseng et al in 2006 explored the use of mini-implants for skeletal anchorage, and to assess their stability and the causes of failure.[34] A total of 45 mini-implants were used in orthodontic treatment with a 2 mm diameter and lengths of 8, 10, 12, 14 mm. The TADs were placed through the cortical bone without flap. After 2 weeks a force of 100-200g was applied by an elastometric chain or NiTi coil spring. The overall success rate was 91.1% with 4 implants loosening after orthodontic force loading.[29]

Direct anchorage and indirect anchorage are the two types of anchorage when establishing treatment mechanics with TADs. When the

force is applied directly to the TAD, direct anchorage occurs, and when bars or wire are attached to the TAD, indirect anchorage results. The anchorage of TADs permits up to 500g of force; whereas; up to 300g of force is required for normal orthodontic mechanics.[8] Due to a study indicating that direct loading may cause overloading of the TAD and thereby lead to failure, indirect anchorage may be a more suitable treatment option when clinically achievable.[30,31]

The increased functions and understanding the additive applications of TADs has made them a more desirable feature when treatment planning. Yet, there can be hurdles to clinical adaptations, such as the comfort level of the patient and orthodontist, and the use of local anesthesia due to the TAD being placed in the oral cavity through the gingiva and bone of the patient. In a 2008 study by Cornelis et al patients' and orthodontists' perceptions of miniplate used for temporary skeletal anchorage was investigated.[32] Seventy-two percent of patients did not mind having the miniplates after a year in place and 82% the surgical experience was better than expected with little to no pain.[37] From the 200 miniplates placed in 97 patients there was a success rate of 92.5%. The study concluded that miniplates are well accepted by patients and providers and are a safe and effective adjunct for complex orthodontic treatments.[32] Although research shows promising data the appreciation and proper training of TADs can maximize clinical success and patient satisfaction.

In 2009, research was conducted to determine the use of TADs in private practice and orthodontic residency programs. The study found that 82.9% of orthodontic residency programs and 69.2% of orthodontists placed TADs. In orthodontic programs 61.9% and 79% of orthodontic practitioners immediately loaded the TADs typically for retraction. Since 2005 there has been a push to increase the use of TADs in residency, didactic and research curriculums (Shirck et al, 2011).[33] A 2014 study distributed a survey to Swiss orthodontists concluded distalization against palatal implants was the most popular treatment plan and the placement varied on the type and size of the TAD, but even more greatly in the sagittal versus the transversal dimension.[34]

In 2020, Baumgaertel et al. determined that palatal miniscrews were more successful than buccal miniscrews and indirect anchorage mechanics had a higher success rate than direct anchorage mechanics when examining the success rates of miniscrews placed by orthodontic residents. The overall success rate for miniscrews was 72.5%. The success rate was 83.9% in the anterior palate, 76% in the palatal alveolar process, 60% in the maxillary buccal alveolar process, and 65.8% in the mandibular buccal alveolar process. The success rate was significantly higher in indirect anchorage (84.2%) compared with direct anchorage (58.8%).[35]

In a 2020 longitudinal study, Keim et al. found that molar protraction was most commonly used, more than 40% of participants used TADs for open bite, molar intrusion, Class II treatment, molar distalization, correction of occlusal-plane cant, or anterior intrusion. The study also concluded that TAD

use in practices fell to 55%, from 70% in 2014 and 61% in 2008. The data continued to show that from 2014 to 2020 cases using TADs dropped from 8 to 5, respectively. Yet, an increase from 35% to 46% of participants found TADs to decrease the number of surgical cases treated.[36]

Although there have been numerous articles showing the impact and effectiveness of TADs in orthodontic treatment as viable tools for absolute anchorage it is still unclear how many orthodontists in the United States currently understand these benefits. A detailed understanding of the factors influencing clinical adoption can help increase its appreciation and practical use in a clinical setting, improving efficiency and efficacy in orthodontic treatment in the United States.

Methods

This study has met the criteria for exemption by the Case Western Reserve University (CWRU) Institutional Review Board (IRB) (Appendix 1). A survey was developed consisting of 28 questions and distributed to orthodontists in the United States via social media orthodontic groups, and in person flier distributions at local and national orthodontic meetings. Orthodontists that were not practicing in a clinical setting and not practicing in the United States were excluded from taking the survey. To achieve 95% confidence level with

a 6% margin of error, a minimum sample size of 254 was deemed appropriate.

To begin, a pilot survey using Redcap® was created and distributed to 10 practicing orthodontists in the US. The feedback was used to recreate the survey to better gather data for analysis. Once the survey was finalized then duplicate the survey creating a test retest reliability survey. The final survey was 29 questions. The number of questions the respondent receives was based on their TAD experience level where those that are more experienced would receive more questions and those with no experience received less questions. The test retest reliability survey can be distributed to 10 participants, and then retaken 3 weeks following their initial survey submission. The survey was distributed via email and reminders were sent 3 weeks after the initial survey was sent. Respondents confirmed their completion of the survey by responding to the email and their response were grouped together for analysis at a later date. The test retest reliability results was used detail the stability of the scores across time. Simultaneously, the primary survey was distributed to practicing orthodontists in the United States using fliers with a QR code and directions on how to use the QR code taking the respondent directly to the survey. This distribution method was completed via mail and at in person orthodontic conferences for the Southern Association of Orthodontists, Southwestern Society of Orthodontists, and Midwestern Society of Orthodontists. The survey was also distributed on the

Facebook orthodontic group “Orthodontic Pearls”, LinkedIn, and Instagram using the surveys unique link. Once the survey distribution was completed the data was analyzed for associations, correlations and causality using SPSS statistical software.

Statistical Analysis

All tests were conducted in statistical package for the social sciences (SPSS 26.0) software. Chi-square tests were (Pearson Chi-Square, Likelihood Ratio, Linear-by-Linear Association) completed for statistical analysis. P values of ≤ 0.05 were considered statistically significant.

Results

Of the 245 total viable surveys taken from the data sample 20.4% have been in practice for 1-5 yrs,19.6% have been in practice for 6-10 years, and 15.5% have been in practice for 30+ years (Figure I). When assessing their job title, 62.7% of those that place TADs are owners/partners, 14.7% are associates, 12.4% work in Hospital/University settings, 7% work at a DSO/OSO and 3% work in a corporate setting (Figure II).

Of the orthodontists that use TADs, 49.1% believe the use of TADs in their office will remain the same, 37.1% believe the use of TADs in their office will increase in the next 5 years, 8.6% are not sure if the use of TADs in their

office will change, 5.2% believe the use of TADs in their office will decrease over the next 5 years (Figure III). Comparatively, when analyzing orthodontist that are currently using TADs and those that report previously using TADs, 48.8% believe TAD use will remain the same in their office, 29.7% believe TAD use will increase in the next 5 years, 12.8% are not sure, and 8.7% believe TAD use will decrease in the next 5 years in their office ($p \leq 0.001$) (Figure IV).The survey population revealed that 57.1% use TADs, 24.1% previously used TADs, 23.3% never used TADs (Figure V). Of those that use TADs 57% have treated 1-5 orthodontic cases with TADs per month in the last year, 20.3% have treated 0 cases with TADs per month in the last year, 13.3% have treated 6-10 cases with TADs per month in the last year (Figure VI). When contrasting orthodontists that currently use TADs and previously use TADs the total number of orthodontic cases treated with TADs per month in the last year was 43.9% for 1-5 case, 40.1% for 0 cases, 9.6% for 6-10 cases, 2.7% for 11-20 cases, 1.6% for 21-30 case and 50+ cases, and 0.5% for 41-50 cases ($p \leq 0.001$) (Figure VII).

From the population that currently use TADs, 65.9% report received their training in TAD placement in a postgraduate setting, 37.2% received their training in TAD placement in a CE/Industry setting, 27.1% indicated they were self-trained in their TAD placement training 7% chose dental school, and 4.7% chose other (Figure VIII). Data analysis showed 54.3% respondents report using TADs in their orthodontic residency program and 45.7% report

not using TADs in their orthodontic residency program. Of those that use TADs 65.1% used them in residency, and those that never used TADs 87.1% did not in their residency program, 66.1% of previous TAD users used them in residency and 33.9% did not ($p \leq 0.001$) (Figure IX).

The study revealed that orthodontists who previously used TADs reported multiple reasons for stopping their use of TADs. 42.4% reported stopping because the same results can be achieved with different biomechanics, 33.9% have stopped using TADs due to patient acceptance of TAD decreased, 32.3% have stopped placing TADs due to additional cost/concerns, 25.4% were concerned about patient comfort/experience, 23.7% reported too many failed TADs, 22% were not the decision maker in the practice,16.9% reported concerns about liability, 8.5% selected “Not applicable”, and 1.7% selected “Not sure/other” (Figure X). In addition, orthodontists that have never used TADs, 43.9% of the time chose additional cost/concerns, 40.4% do not use TADs because they are not the decision maker in the practice, 28.1% do not use TADs because they are concern about liability, 28.1% do not use TADs because they are not knowledgeable about it (Figure XI).

Of those that currently use TADs 44.2% have used TADs for maxillary posterior intrusion, 41.1% have used MARPE in their office. In addition, previous TAD users, 20.3% have used TADs for maxillary posterior intrusion, while 11.9% have used MARPE in their office (Figure XII). Of those that use TADs self-drilling mini-screws was the most common type of TAD used at 70.5%, self-tapping mini-screws was next at 26.4%, followed by miniplates use at 10.1%, and 7% were not sure (Figure XIII). Orthodontists that use TADs 68.7% place TADs themselves in the majority of their treatment planned TADs, 21.7% have OMFS place the majority of their treatment planned TADs, 6.1% have periodontists place the majority of their treatment planned TADs, 1.7% have another orthodontist place the majority of their treatment planned TADs, 0.9%% have a general dentist place the majority of their treatment planned TADs, 0.9% chose “other” to place the majority of their treatment planned TADs (Figure XIV). Fixed appliances and TADs were the most common combined modalities at 66.7%, expanders and TADs followed 36.2%, then clear aligners and TADs at 24.8%, and 2.3% respondents chose “other” (Figure XV).

Discussion

In recent years, TAD use has become increasing popular among orthodontists. The aim of this study was to understand how TADs are being used in the United States by practicing orthodontists. There have been previous studies that investigated trends of TAD usage in the United States and internationally. The study conducted by Keim et al. 2020, concluded that practicing orthodontists that treated at least one case with TAD fell to 55% in 2020 from 70% in 2014 among practicing orthodontists. The results of this study revealed that TAD usage changed by -15% at a confidence level of 99% (55% in previous study vs 66% in our study). One explanation could be that as new orthodontic graduates are completing their orthodontic residency training and entering the workforce, while those that have been in practice longer are retiring there has been an increase in the amount of orthodontists that are using TADs.

Data analysis also revealed that the demographics of orthodontists that use TADs changed. Kiem et al. showed that the average years in practice increased from 22 years to 26 years from 2014 to 2020, our study showed different results. The most common group of orthodontists using TADs were 1 to 5 years at 20.4%, followed by 6-10 years at 19.6%, and 30+ years at 15.5%. Those that graduated from orthodontic residency in the last 1 to 5 years had a higher usage rate than those that graduated in during any other period. Kiem et al. did not have consistent longitudinal information to compare

geographical regions. In our study, it was determined that no particular U.S. region (Northeast, South, Midwest, or West) had a statistically significant usage of TADs. Taking a step further, our study analyzed the position each orthodontist held. We concluded that most orthodontists that use TADs were owners or partners (62.7%), versus working as an associate (14.7%), or working in a corporate (3%), DSO/OSO (7%), or Hospital/University setting (12.4%). A possible explanation is there are additional expense for the practicing orthodontist such as the TADs themselves and their armamentarium, as well as having the patient buy in to the TAD-assisted treatment plan. A younger orthodontist that is an owner/partner may be more likely to use TADs because they have more control over decision making in their practice setting when purchasing supplies, treatment planning, and is able to communicate the benefits of using a TAD to their patient effectively would be more capable.

This study's survey was also able to detail that there are factors that influence the use of TADs in practice by orthodontists. Kiem et al. concluded that more orthodontists were trained in skeletal anchorage in their postgraduate course at 61%, 30% used a proprietary course, 30% chose "Self", 9% chose dental school, and 0% other. This result is similar to our study where those currently placing TADS, 65.9% received their training in TAD placement in a postgraduate setting, 37.2% received their training in TAD placement in a CE/Industry setting, 27.1% indicated they were self-

trained in their TAD placement training 7% chose dental school, and 4.7% chose other. In addition, our study assessed orthodontists that do not use TADs. That population had a higher percentage (82.5%) of no training in their orthodontic residency program than those that do use TADs (65.1%) . One explanation could be that the comfort with using TADs by the orthodontist and the ability to communicate the benefit to the patient may take time to develop. Orthodontic training programs provide a controlled clinical environment for orthodontic residents to develop the confidence to use TADs which in turn extends to their postgraduate application.

When comparing results from Kiem et al., most TADs placed were completed by the orthodontist instead of being referred for placement. This is consistent in our study. In the previous study, 67% of orthodontist placed mini crews in 2014 which decreased to 55% in 2020. When compared to oral surgeons during the same period 28% placed them in 2014 and 29% in 2020, periodontists placed 4% in 2014 and 15% in 2020, and general dentists placed 1% in 2014 and 2% in 2020. Our study show similar results where 68.7% of orthodontists placed TADs themselves, 21.7% have oral surgeons place the majority of their treatment planned TADs, 6.1% are placed by periodontists, 1.7% have another orthodontist place their TADs, 0.9%% use a general dentist, and 0.9% chose “other” to place the majority of their treatment planned TADs. One reason for these results could be that orthodontists want to have more control of the placement as well as

implement immediate loading of the TAD. In addition, a reason why TADs are placed by other specialists could be due to the extended chair time needed to place them which is not ideal for a busy orthodontic practice, the digital imagining (CBCT) necessary, and the need to place local anesthesia due initial insertion.

According to Keim et al, when looking at how TADs are used in combination with other modalities fixed appliance were the most common, which is similar to our study. In the previous study, in 2020, 22 respondents used fixed appliance only, 16 used aligners only 21 used fixed appliances and aligners, and 21 used all cases. In our study, out of 91 respondents, fixed appliances was the most common response at 66.7%, expanders followed at 36.2%, then clear aligners at 24.8%, and “other” was chose by 2.3%. One reason for fixed appliances and TADs having a higher combination of use could be due to the advantage of supportive anchorage that wires and brackets provide over clear aligners. In addition, not all patients are candidates and treatment planned with expanders, which could contribute to the reduced number of expander and TAD combinations.

Kiem et al assessed skeletal anchorage with TADs in various case types. The study concluded that molar protraction when using TADs was used most routinely. In addition more than 40% of the participants used TADs for molar intrusion at least occasionally. This is different from our results, where orthodontists most commonly used TADs in maxillary posterior

intrusion (44.2%). In the previous study, MARPEs were not evaluated. Yet in this study, its use with MARPEs (41.1%) were less popular among orthodontists when compared to maxillary posterior intrusion. Both studies were similar in that 40.3% have used TADs for maxillary posterior mesialization and 38% have used TADs for mandibular posterior mesialization. This consistency could be due to how difficult it is to establish anchorage in order to intrude maxillary molars and the treatment planning advantage a TAD can give to the provider. The patient's comfort when using a MARPE, in addition to the small age group that sees the greatest effects may be leading factors to the popularity of MARPEs not being at the top. Yet, in time as more new orthodontists enter the profession and older orthodontists retire these factors impact TAD use may change.

Conclusion

Current TAD use by orthodontic practitioners in the United States is popular with 57.1% of orthodontists using TADs in practice and 49.1% have an increased interest in continuing to use them at the same or higher rate over the next 5 years. When assessing factors that influence clinical adoption, most orthodontists placing TADs received their training in a postgraduate setting (65.9%) and 66% placed at least 1 TAD in their post residency career. The most common group of orthodontists using TADs had 1 to 5 years practice and were owners/partners (20.4% and 62.7%, respectively). TADs

have various uses to assist in achieving treatment planning goals. Maxillary expansion is the second most common way in which people use TADs (44.2%) behind maxillary posterior intrusion (41.1%). Fixed appliances in combination with TADs was the most common combination modality selected (66.7%).

Strengths

This study provided several benefits to previous knowledge surrounding TAD use in the United states. How TADs are used, the work setting and job title of orthodontists currently using, having previous use, and having never used TADs was obtained. We were able to gathering a better understanding the reason why the respondent chooses not to use TADs. The most common clinical use for TADs was achieve in addition to MARPEs.

Limitations

The Power was determined to have a confidence level of 88.5%. There was a region bias. When looking at the states and regions captured in the study it was determined that states visited for conferences where the most

represented in the survey. The surveyed population had a reduction in the respondents towards the end of the survey due to a branching issue.

Recommendations for future study

- Investigate TAD training in residency by determining how many cases with TADs residents are treating and how many TADs are being placed. To better understand the adoption benefits and restrictions post residency.
- Expand on demographic information by adding questions about age, sex, practice income to determine how those variables influence if orthodontists use TAD.
- Increase respondents by surveying a larger population of orthodontists to assess TAD use in the U.S. with similar questions to this study to better assess accuracy of data
- Create a survey assessing patient population where orthodontists are asked questions about the age demographic of the patient who receives TADs and compared it to cases treated with TADs to better understand case acceptance
- A longitudinal study assessing MARPE use versus other TAD uses to determine if MARPEs are becoming more popular or less popular.

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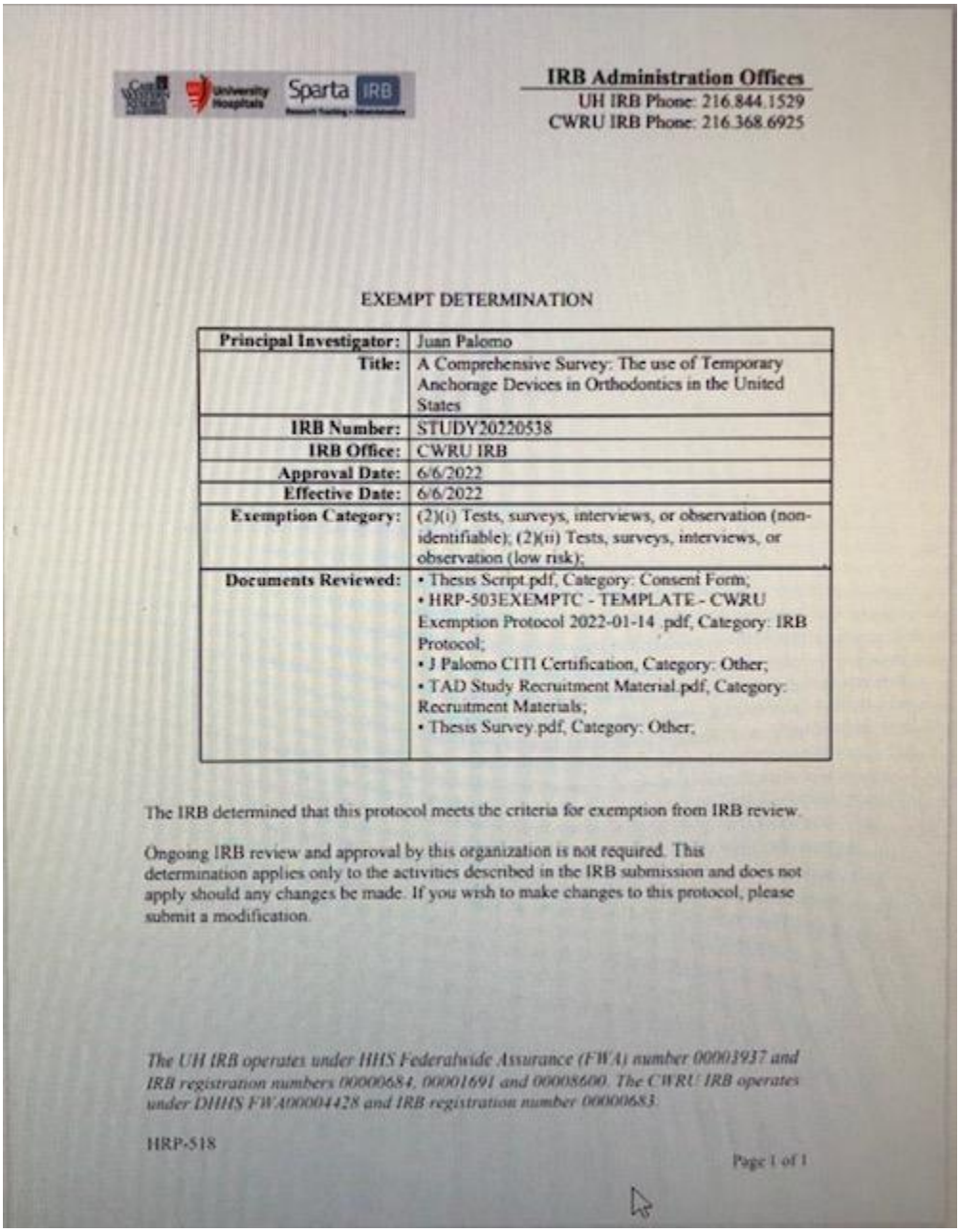
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APPENDICES

Appendix A: IRB Exemption



IRB Administration Offices
UH IRB Phone: 216.844.1529
CWRU IRB Phone: 216.368.6925

EXEMPT DETERMINATION

Principal Investigator:	Juan Palomo
Title:	A Comprehensive Survey: The use of Temporary Anchorage Devices in Orthodontics in the United States
IRB Number:	STUDY20220538
IRB Office:	CWRU IRB
Approval Date:	6/6/2022
Effective Date:	6/6/2022
Exemption Category:	(2)(i) Tests, surveys, interviews, or observation (non-identifiable); (2)(ii) Tests, surveys, interviews, or observation (low risk);
Documents Reviewed:	• Thesis Script.pdf, Category: Consent Form; • HRP-503EXEMPTC - TEMPLATE - CWRU Exemption Protocol 2022-01-14 .pdf, Category: IRB Protocol; • J Palomo CITI Certification, Category: Other; • TAD Study Recruitment Material.pdf, Category: Recruitment Materials; • Thesis Survey.pdf, Category: Other;

The IRB determined that this protocol meets the criteria for exemption from IRB review.

Ongoing IRB review and approval by this organization is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If you wish to make changes to this protocol, please submit a modification.

The UH IRB operates under HHS Federalwide Assurance (FWA) number 00003937 and IRB registration numbers 00000684, 00001691 and 00008600. The CWRU IRB operates under DHHS FWA00004428 and IRB registration number 00000683.

HRP-518

Page 1 of 1

Appendix B: Abbreviation Key

TAD: Temporary Anchorage Device

MARPE: Mini-screw Assisted Rapid Palatal Expander

GRAPHS

Figure I

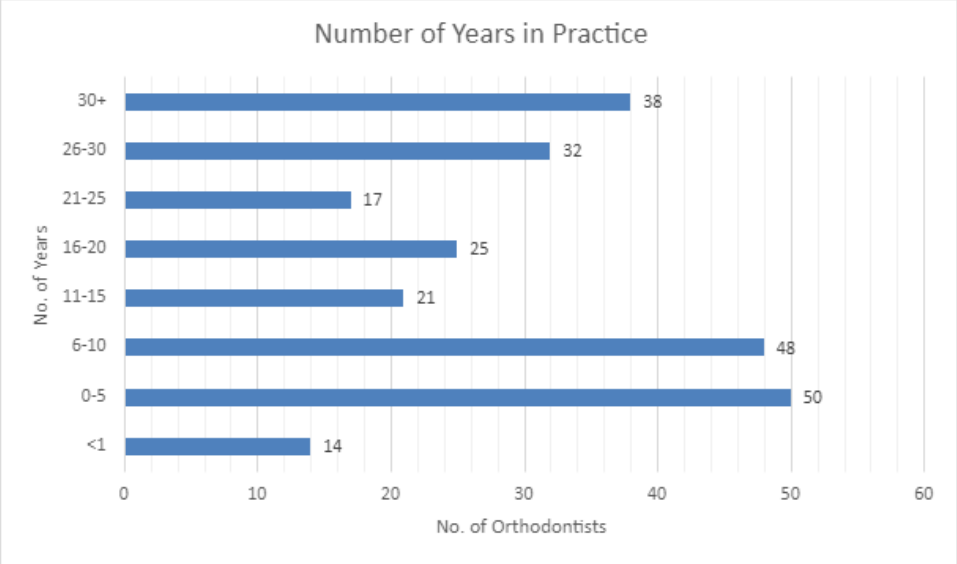


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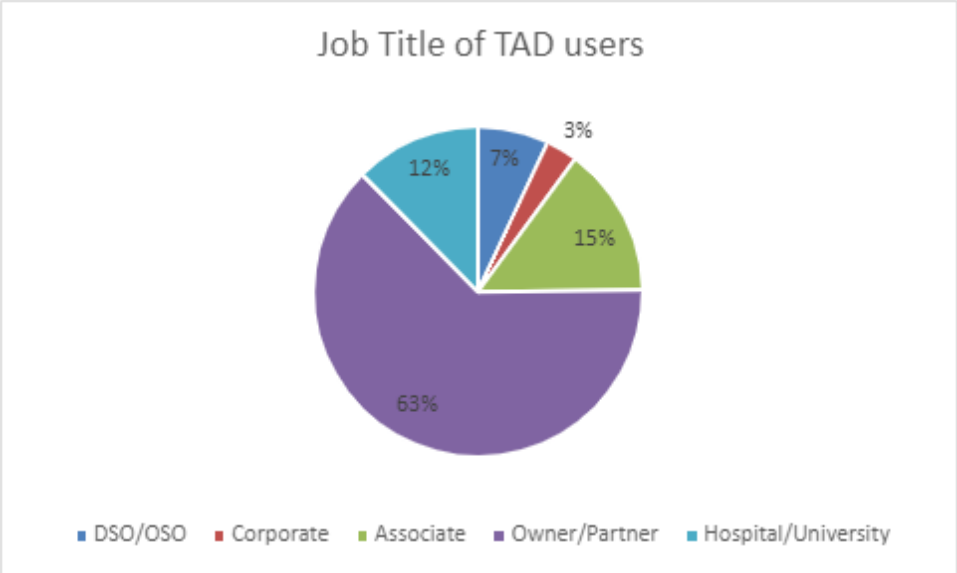


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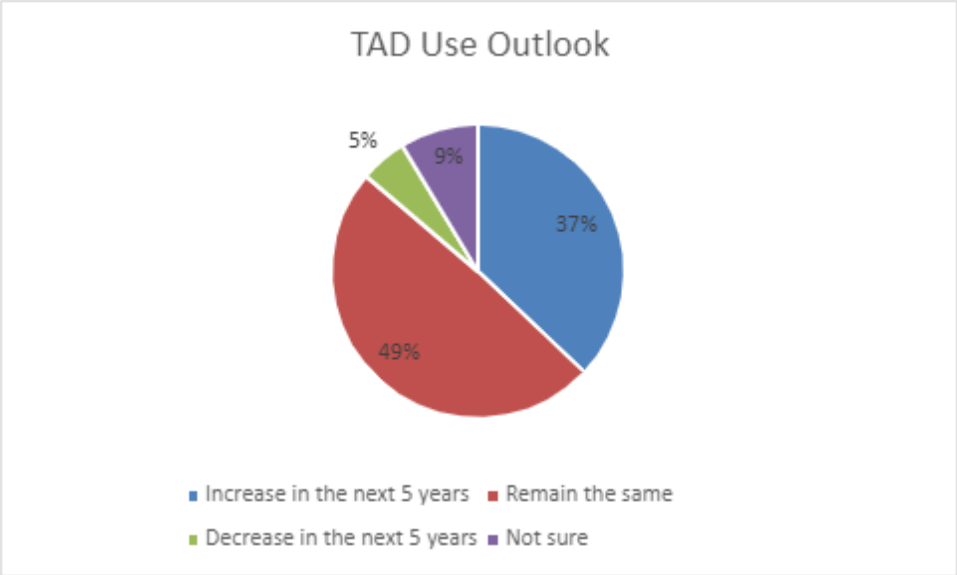


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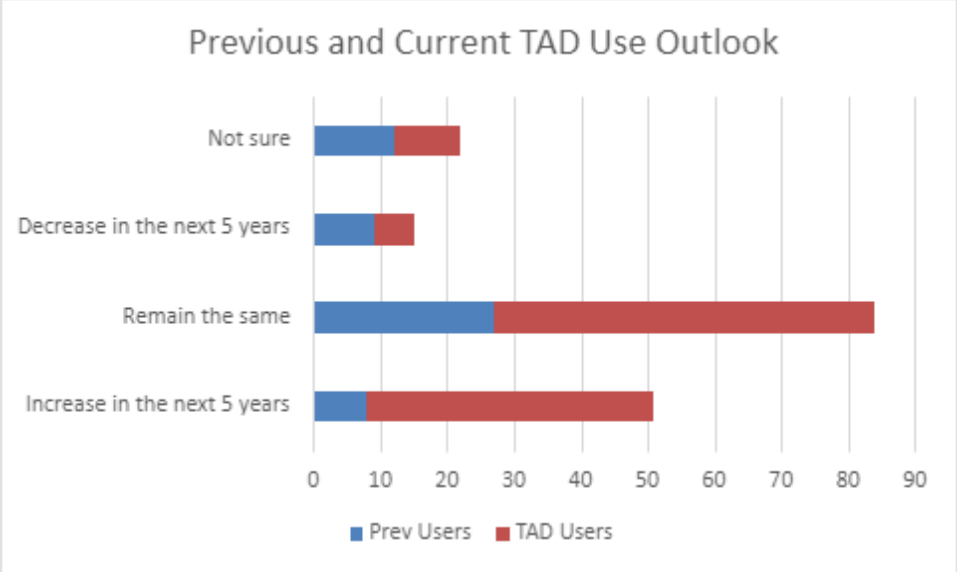


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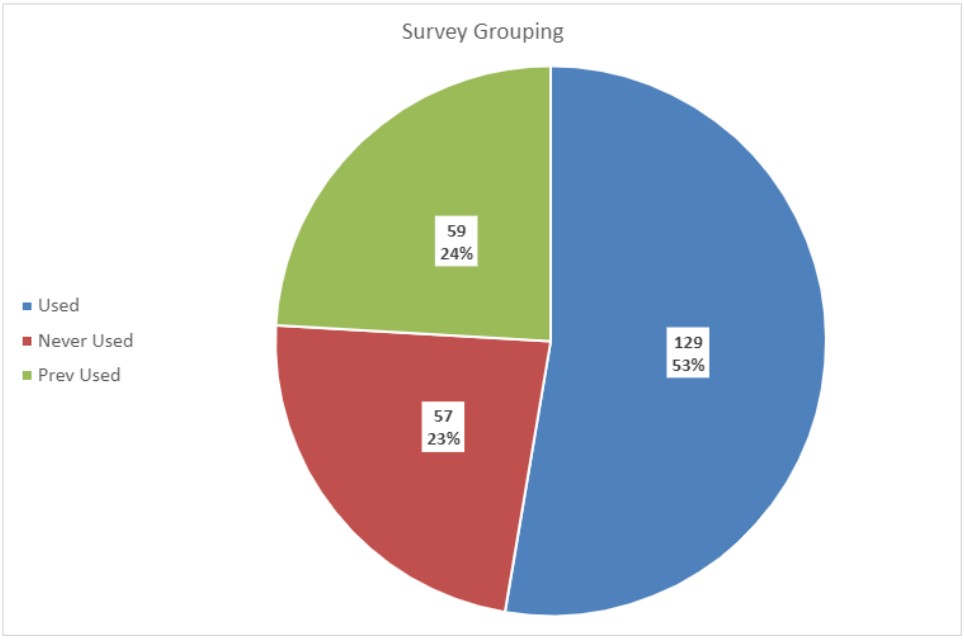


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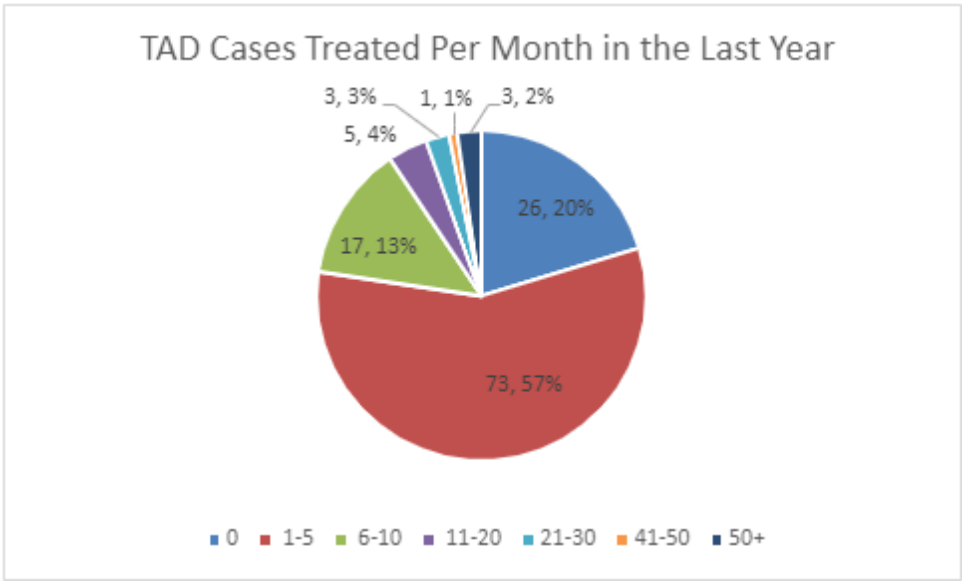


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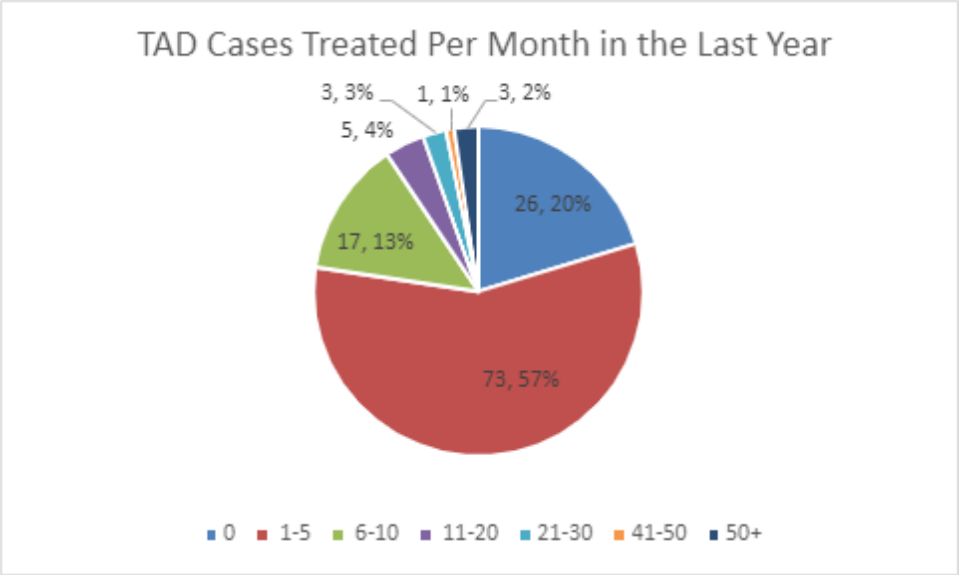


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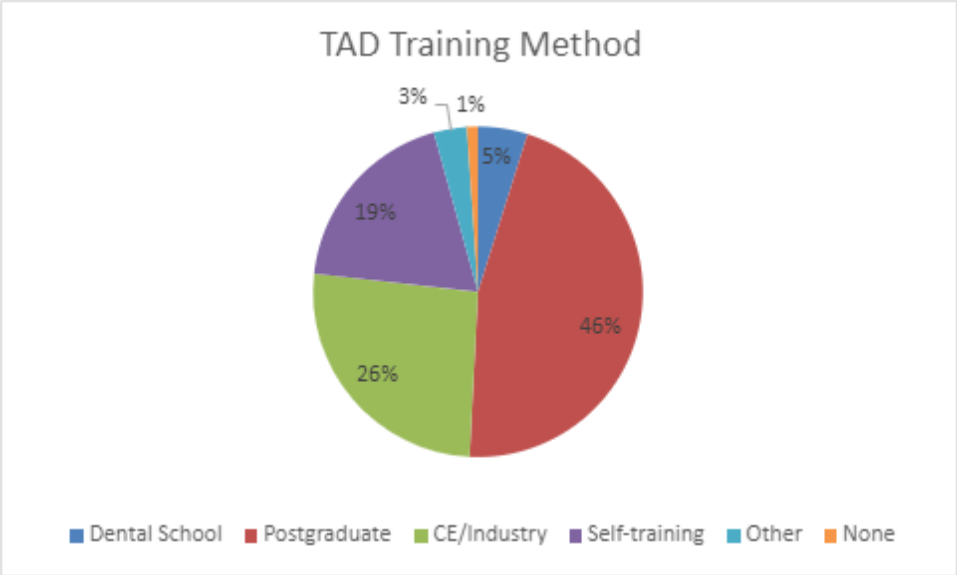


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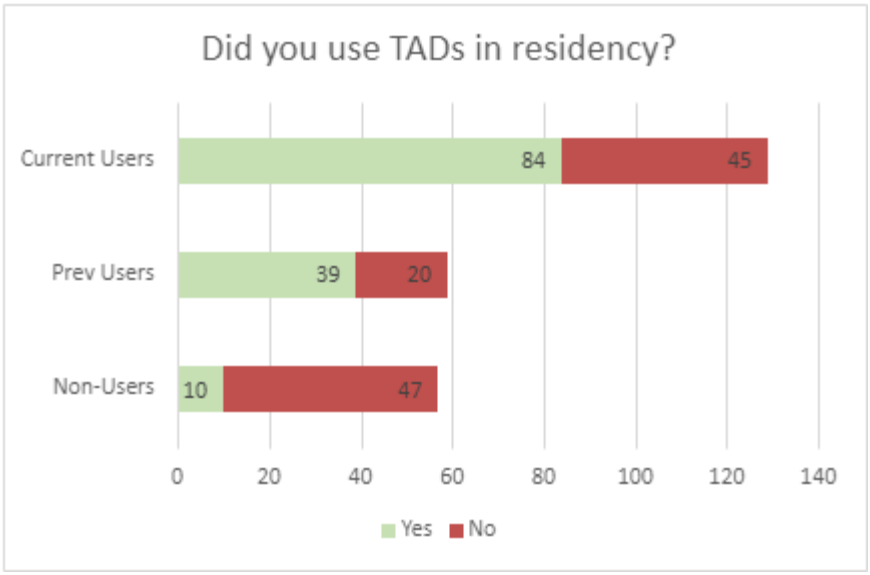


Figure X

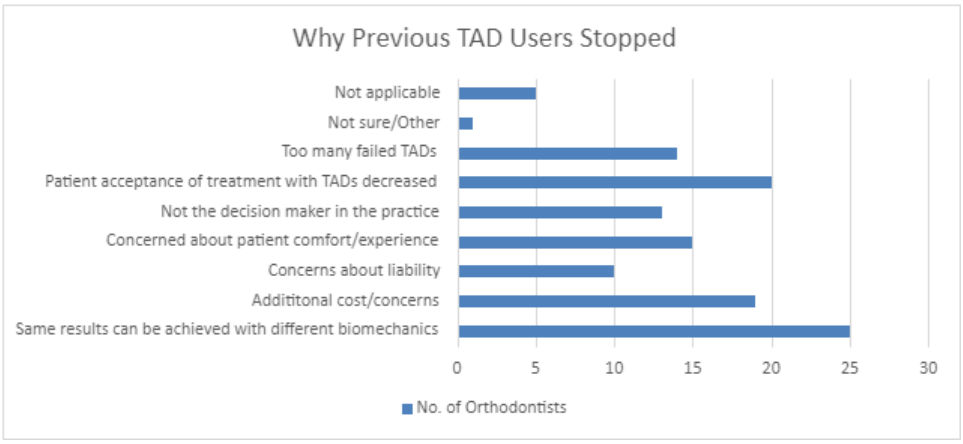


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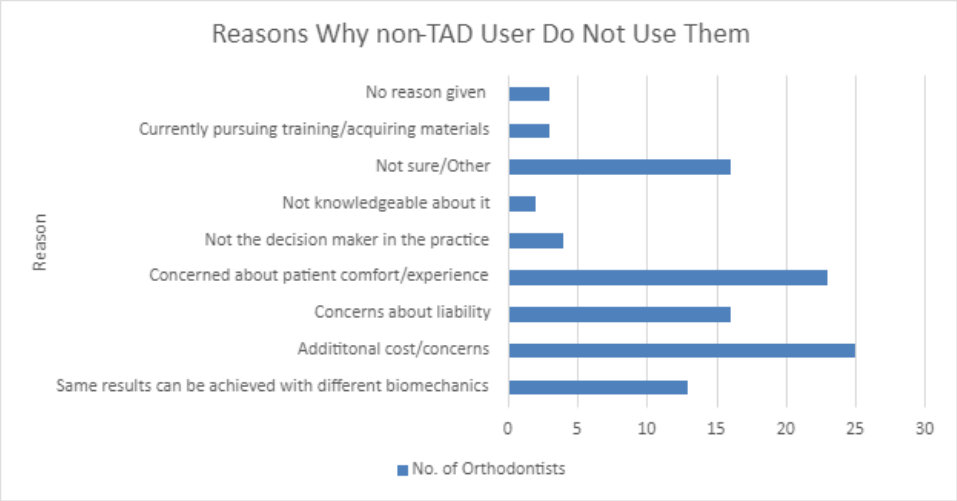

Reasons Why non-TAD User Do Not Use Them
Reason
No reason given
Currently pursuing training/acquiring materials
Not sure/Other
Not knowledgeable about it
Not the decision maker in the practice
Concerned about patient comfort/experience
Concerns about liability
Addititonal cost/concerns
Same results can be achieved with different biomechanics
0
5
10
15
20
25
30
No. of Orthodontists

Figure XII

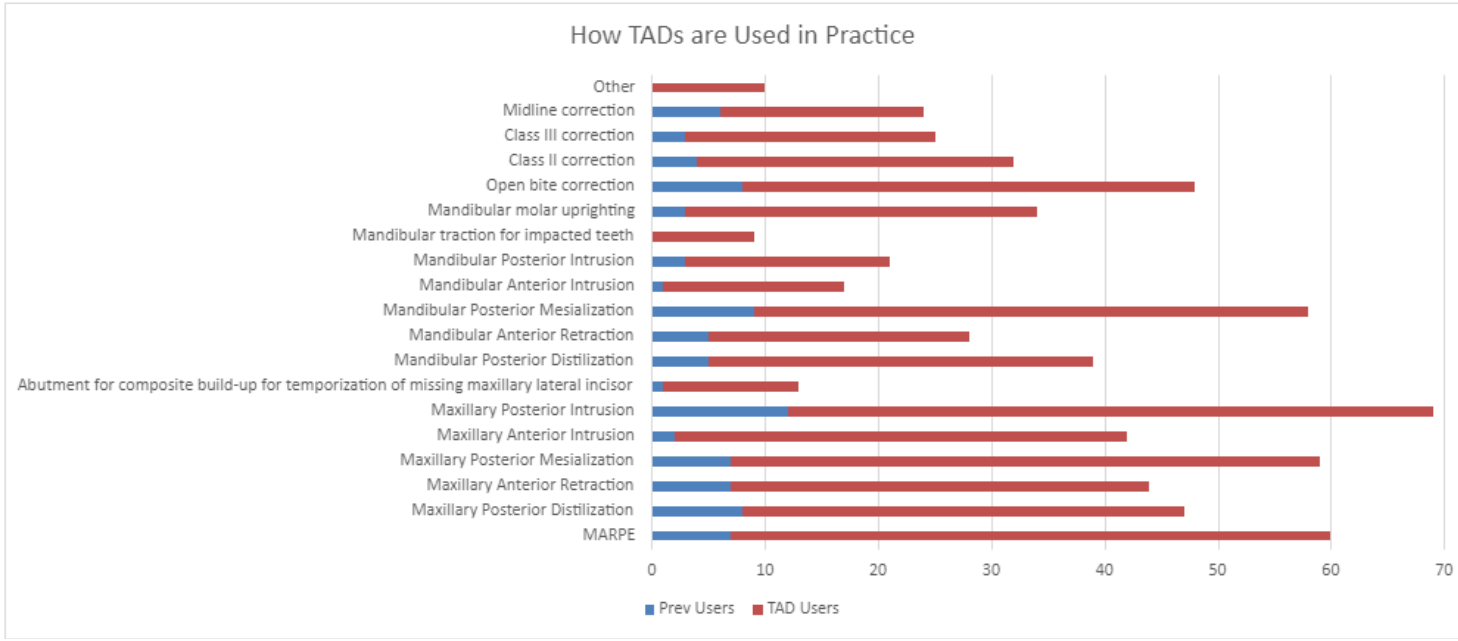

How TADs are Used in Practice
Other
Midline correction
Class III correction
Class II correction
Open bite correction
Mandibular molar uprighting
Mandibular traction for impacted teeth
Mandibular Posterior Intrusion
Mandibular Anterior Intrusion
Mandibular Posterior Mesialization
Mandibular Anterior Retraction
Mandibular Posterior Distilization
Abutment for composite build-up for temporization of missing maxillary lateral incisor
Maxillary Posterior Intrusion
Maxillary Anterior Intrusion
Maxillary Posterior Mesialization
Maxillary Anterior Retraction
Maxillary Posterior Distilization
MARPE
0
10
20
30
40
50
60
70
Prev Users
TAD Users

Figure XIII

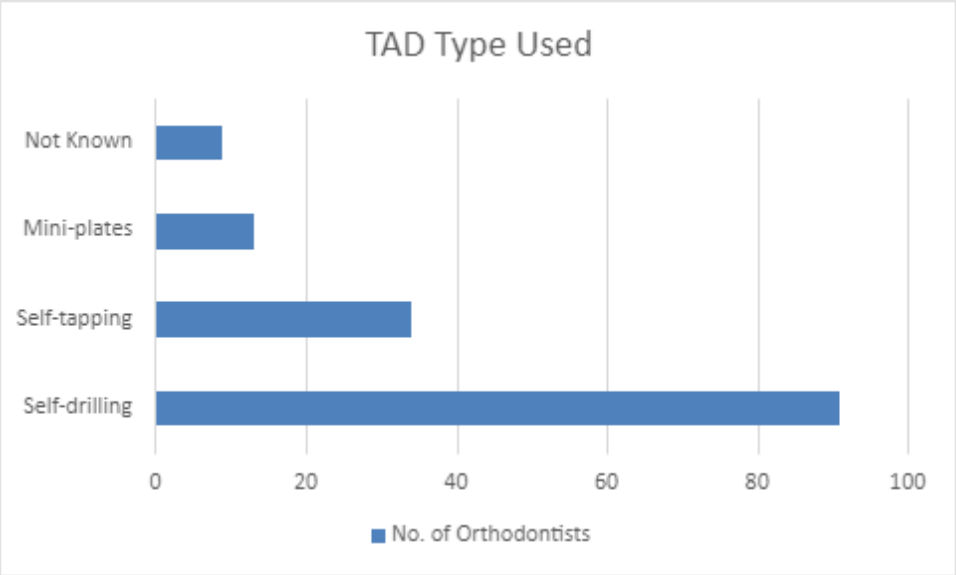


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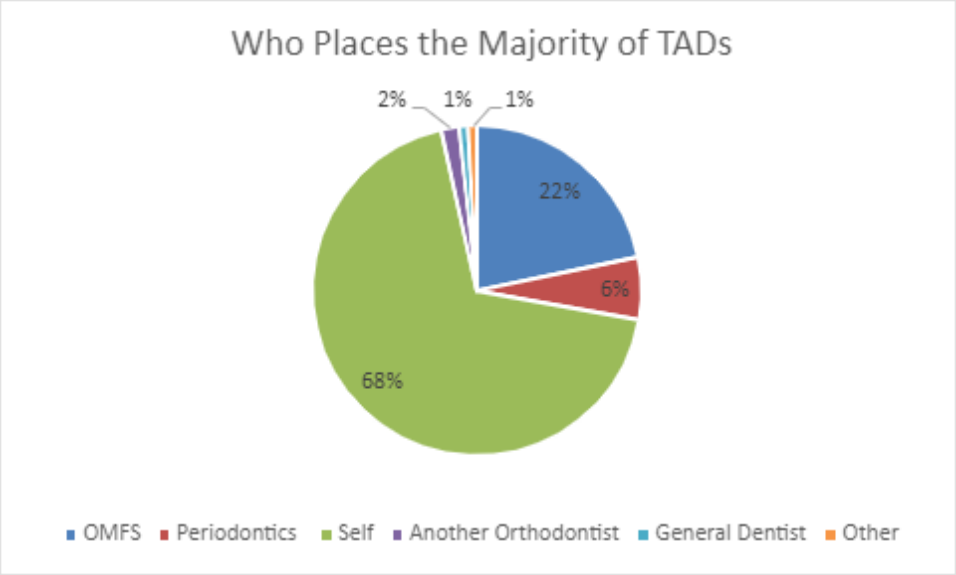
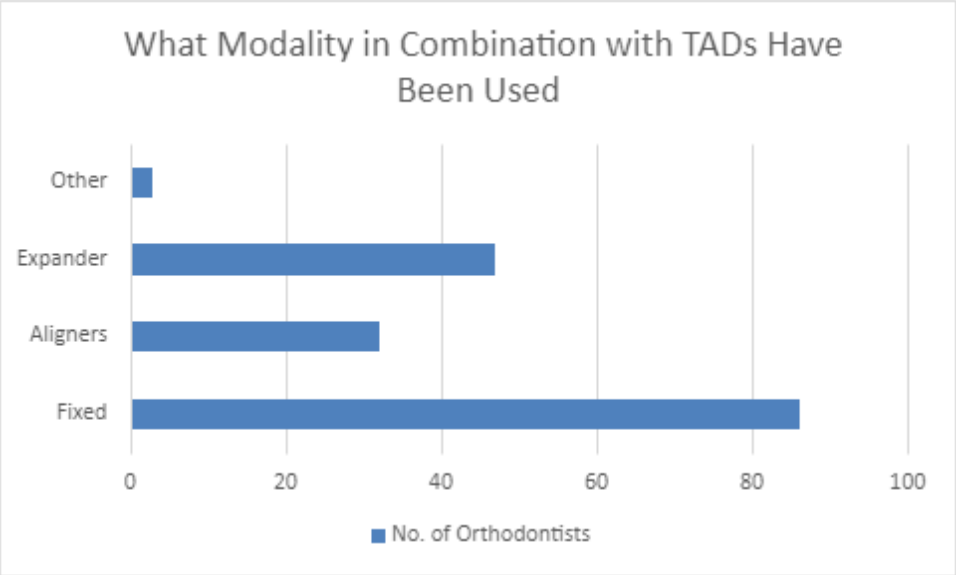


Figure XV


What Modality in Combination with TADs Have Been Used
Other
Expander
Aligners
Fixed
0
20
40
60
80
100
No. of Orthodontists