INFLUENCE OF SUTURE TECHNIQUE ON RIDGE DIMENSIONS AND KERATINIZED TISSUE AFTER ALVEOLAR RIDGE PRESERVATION: A PILOT STUDY

A THESIS IN
Oral and Craniofacial Sciences

Presented to the Faculty of the University
of Missouri-Kansas City in partial fulfillment of
the requirements for the degree

MASTER OF SCIENCE

by
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Kansas City, Missouri
2020

INFLUENCE OF SUTURE TECHNIQUE ON RIDGE DIMENSIONS AND KERATINIZED TISSUE AFTER ALVEOLAR RIDGE PRESERVATION: A PILOT STUDY

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University of Missouri-Kansas City, 2020

ABSTRACT

The alveolar ridge preservation (ARP) procedure was designed to minimize bone loss following tooth extraction to allow for implant placement in the prosthetically-driven position, and reduce the need for subsequent grafting procedures. The aim of this study was to evaluate how two suturing techniques affect the healing morphology of hard and soft tissue following ARP.

A randomized controlled pilot study was designed to compare the outcome of ARP using an external crossing horizontal mattress suture (control) versus an internal crossing horizontal mattress suture (test). After at least 15 weeks healing from extraction and ARP, subjects were evaluated clinically for changes alveolar ridge height, width, and extent of keratinized tissue as measured by any shift in the mucogingival junction (MGJ) position.

Eleven patients with twelve tooth sites met the inclusion criteria and completed the study. The loss of lingual alveolar width was significantly lower for the test suture group 0.51 ± 0.52 mm than the control suture group 1.58±0.81 mm (p=0.03). The loss of buccal height was significantly lower for the control group 0.07± 0.90 mm than test group 1.90±1.51 mm (p=0.04). In contrast, there was no significant difference between the test and control suture groups when comparing buccal alveolar width or lingual alveolar height. The mean

change in MGJ position was -0.20±0.31 mm for the control group and -0.05±0.83 mm for the test group, but the difference was not statistically or clinically different.

The results of this pilot study suggest that the choice of suture technique might influence the resultant lingual width and buccal height after ARP. Stronger evidence might be obtained in future studies through a larger scale clinical trial and by measuring alveolar changes by cone beam computed tomography (CBCT).

APPROVAL PAGE

The faculty listed below, appointed by the Dean of the School of Dentistry have examined a thesis titled "Influence of Suture Technique on Ridge Dimensions and Keratinized Tissue after Alveolar Ridge Preservation: A Pilot Study," presented by Justin Tullis, candidate for the Master of Science degree, and certify that in their opinion it is worthy of acceptance.

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ACKNOWLEDGMENTS

I would like to express my sincere appreciation and give thanks to:

Dr. Mary Walker, for her encouragement, guidance, and expertise throughout my residency and OCS training at the UMKC School of Dentistry.

Dr. Keerthana Satheesh, for her encouragement, guidance, and expertise throughout my residency training at the UMKC School of Dentistry.

Dr. Scott Gruwell, for his expertise, feedback, and time.

Dr. Joanna Scott, for her expertise in biostatistics, feedback, and time.

Dr. Erin E. Bumann, for her expertise, feedback, and time.

Dr. Mabel Salas, for her assistance and guidance.

Ms. Barbara Adkins, for her assistance with the Institutional Review Board.

Ms. Marie Thompson, for her assistance with formatting.

Jessica Moniz, for her assistance with data collection.

Jania Billups, for her support and administrative assistance.

Erin Liljequist, for her support and administrative assistance.

Patrick Dixon, for his support and administrative assistance.

The many dental students that assisted me during surgery and clinical measurements.

The Advanced Periodontics clinic staff for their support: Rachel Muleski, Martha Self, and Leslie Mohan.

Osteogenics, for their generous donation of allograft bone, barrier membranes, and suture.

My family, for their love, support, and encouragement throughout my training.

CHAPTER 1

INTRODUCTION

Tooth Loss

Numerous pathologies may compromise the health and prognosis of a tooth: dental caries, periodontal disease, crown or root fracture, root resorption, or failed endodontic therapy. When a compromised tooth cannot be restored or maintained, extraction is usually indicated. The natural healing process following tooth extraction includes resorption of the alveolar bone that is no longer stimulated by a tooth. The full extent of alveolar bone loss depends on the clinician's extraction technique, how the patient's phenotype affects wound healing, and if any attempt is made to preserve the alveolar ridge.

Tooth Replacement: Indications and Options

When a permanent, non-third molar tooth is lost, the dentist will usually recommend replacement of that tooth with some type of prosthetic device to restore the patient's form, function, and esthetics. If the tooth is not replaced then functional problems often result: occlusal shift, tipping of adjacent teeth, bone loss and accompanying gingival recession at adjacent teeth, supra-eruption of the opposing dentition, decreased chewing function, increased loading forces on remaining teeth, and altered phonetics of speech. Esthetic compromise may also result from altered appearance in facial profile, smile, and speech with negative social and economic consequences.

There are three main options to replace a missing tooth: a removable denture, fixed partial denture (i.e. bridge), or a dental implant supported dental prosthesis. Patients and their clinicians frequently choose an endosseous implant because it most closely resembles a natural tooth in form, function, and esthetics. A prosthetic crown is attached via an abutment

to the titanium fixture that is integrated into the alveolar bone of the jaws. Not every patient or tooth site is a good candidate for a dental implant. There must be adequate hard and soft tissue to support the implant. Local and systemic risk factors for peri-implant disease should be controlled as much as possible.

Alveolar Ridge Changes after Tooth Extraction and Impact on Dental Implant Placement

Alveolar ridge resorption following tooth extraction is a well-established phenomenon (Lam 1960; Atwood 1971). Approximately 50% of the alveolar ridge width may be lost within the first 12 months following single tooth extraction (Schropp L 2003).

Early studies on the effects of tooth extraction on alveolar ridge morphology found that both lingual and buccal aspects of bone resorb, but the buccal side undergoes more tissue loss in both the maxilla and mandible (Pietrokovski J 1967). A systematic review of alveolar bone dimensional changes of post-extraction sockets found that loss of ridge width (mean 3.87mm) was greater than loss of ridge height (mean 1.67mm) (Van der Weijden et al. 2009). In 2012, another systematic review analyzing dimensional changes post-extraction showed horizontal bone loss of 29-63% and vertical bone loss of 11-22%. Rapid bone reduction occurred in the first 3-6 months followed by more gradual reductions thereafter (Tan et al. 2012). Alveolar bone resorption may compromise the ability to restore the form, function, and esthetics of the dentition. The remaining bone may be inadequate to support a restoration using an osseointegrated dental implant, especially approaching the esthetic zone. Increasingly, dental surgeons are placing implants not just where bone is available, but in the ideal location based on a restoration-driven treatment plan. The patient does not simply want an implant, but a functional and esthetic prosthesis for their missing teeth.

Resorptive bone loss often most significantly affects the buccal aspect, especially in the maxillary anterior, or esthetic zone, where the edentulous ridge resorbs in a posterior direction. When there is inadequate bone to place an implant in the ideal location for a successful restoration, additional site preparation surgeries, such as guided bone regeneration may be required.

Keratinized Tissue and the Relationship to Dental Implant Application

In addition to inadequate bone support for a dental implant, there can also be inadequate soft tissue support. Two types of oral soft tissue include a thin, movable mucosa (alveolar mucosa) and a firm, attached, and keratinized tissue surrounding the teeth. A distinct transition is normally detectable between attached, keratinized gingiva and alveolar mucosa. This is called the mucogingival junction (MGJ). Keratinized tissue is more resistant to stretching and abrasion. In health, this tissue is firmly attached to teeth and supporting bone and protects the underlying structures from the daily challenges of eating and tooth brushing. It has been suggested that a certain thickness or width of keratinized tissue (KT) or gingiva around teeth may be important to sustain gingival health but the amount is controversial. It was previously reported that minimum zones of keratinized and attached gingiva were required for long term stability (Lang and Loe 1972; Wilson and Maynard 1981). Later studies found it is possible to maintain the periodontium in the absence of KT as long as supporting soft tissues are well-maintained in a state of minimal-to-no inflammation (Kennedy et al. 1985; Freedman et al. 1999). The minimum amount of keratinized tissue needed to sustain periodontal health is disputed, and there may be no minimum, in the absence of plaque and inflammation (Kim and Neiva 2015).

The soft tissues around dental implants are structurally and functionally different than around teeth. Peri-implant tissues attach by a junctional epithelium (Listgarten et al. 1991). Unlike the perpendicular inserting fibers of the periodontium, peri-implant tissues form a connective tissue cuff that surrounds the epithelial attachment (Berglundh et al. 1991; Ruggeri et al. 1992). Peri-implant tissues are also less vascular, compared to the periodontium (Berglundh et al. 1994). These tissue differences make peri-implant tissues more susceptible to plaque-induced inflammation and less resistant to infection.

The next question is whether a certain amount of KT is required for peri-implant tissues. In a systematic review aimed to determine the significance of KT on implant health, the authors concluded that a lack of KT led to increased plaque accumulation, tissue inflammation, mucosal recession (MR), and attachment loss (AL) of the peri-implant tissues. A band of at least 1-2mm of KT may be adequate to maintain those parameters of implant health (Lin et al. 2013). Sufficient KT surrounding the implant is important for long-term health and stability of the site. Several systematic reviews have concluded that keratinized tissue is essential for peri-implant health (Gobbato et al. 2013; Lin et al. 2013; Brito et al. 2014).

Alveolar Ridge Preservation following Tooth Extraction

To minimize alveolar bone volume loss following tooth extraction, a technique called alveolar ridge preservation (ARP) emerged in the 1980's (Avila-Ortiz et al. (2014). Also known as socket preservation, ARP is a bone grafting technique, usually employed to prepare an extraction site for future dental implant placement. A substantial body of evidence has

now demonstrated that ARP minimizes the bone loss experienced following tooth extraction (Ten Heggeler et al. 2011).

A systematic review of randomized controlled trials found that ARP via socket filling with a bone graft can be an effective therapy to minimize physiologic bone loss after extraction of teeth, in both the horizontal and the vertical dimension (Avila-Ortiz et al. 2014).

There are a great variety of protocols and materials that have been used for ARP. A typical protocol involves extracting the tooth as atraumatically as possible, cleaning the socket of any granulation tissue, placing a particulate bone graft material into the socket, covering with a membrane and suturing, with or without primary closure of the wound. Additional studies have shown that the best preservation of bone and keratinized tissues following tooth extraction occurs with minimal flap elevation and when a bone graft is placed and covered with an exclusionary membrane that remains exposed without primary closure (Engler-Hamm et al. 2011; Barone et al. 2013; Barone et al. 2014; Park et al. 2016; Hong et al. 2019).

Various grafting materials have been used over the years including: autografts, allografts, xenografts, and alloplasts (Avila-Ortiz et al. 2014). Alveolar ridge preservation is most commonly performed using either allograft or xenograft particulate bone and non-resorbable suture. A variety of membranes, including resorbable and non-resorbable, have been used to contain the graft and block or delay epithelial down growth into the socket. Several grafting materials have achieved reduced alveolar bone loss compared to extraction alone (Arbab et al. 2016; Natto et al. 2017; Serrano Mendez et al. 2017). Several wound healing studies have demonstrated good results using different combination of mineralized

and demineralized bone allograft (Wood and Mealey 2012; Eskow and Mealey 2014; Borg and Mealey 2015; Demetter et al. 2017).

Both mineralized and demineralized allograft bone have shown the ability to minimize ridge resorption after tooth extraction (Wood and Mealey 2012). Reported benefits of mineralized bone include radiopacity and its ability to function as an osteoconductive scaffold to maintain space during new bone formation. Demineralized bone is favorable for its reported osteoinductive potential, where the demineralization process liberates bone morphogenetic proteins (BMPs) that stimulate new bone growth (Burchardt 1983; Goldberg and Stevenson 1987; Piattelli et al. 1996). Combining the benefits of both graft materials in a 70:30 mixture was shown to maintain equivalent ridge dimensions and produce significantly more vital bone percentage compared to 100% mineralized bone after four months of healing (Borg and Mealey 2015).

Graft material may be retained with bio-resorbable, or non-resorbable membranes. Non-resorbable membranes are stable in the oral cavity, but often require removal at a subsequent appointment. When primary closure of a tooth socket is obtained, it requires the release of the buccal soft tissue from its normal position in order to advance it over the socket opening to close the wound. The primary closure technique emerged from a belief that all bone grafts must have primary closure for proper healing. But tooth sockets, especially when four bony walls are present, provide a more structurally stable environment for bone grafting. Attempting primary tissue closure over a tooth socket causes more patient discomfort, can unfavorably shift the MGJ, and damage interdental papillae (Barone et al. 2013). Shifting the MGJ via primary closure may leave the future implant site with insufficient keratinized tissue, leading to greater risk of inflammation and eventual plaque-induced destruction of

peri-implant tissue. Furthermore, obtaining primary closure of the extraction socket requires reflecting a buccal mucoperiosteal flap, which compromises blood supply to the thin buccal plate of bone and may promote more buccal bone resorption. A flapless, or minimal flap approach retains more blood supply has been shown to reduce buccal bone loss (Chu et al. 2015), and eliminates the need for flap repositioning for primary closure. Several studies have shown good healing results without primary closure over the barrier membrane that covers the graft (Darby et al. 2009; Engler-Hamm et al. 2011; Ten Heggeler et al. 2011).

Suturing to Stabilize Socket Graft – External Crossing Suture

Following graft and membrane placement, sutures stabilize and retain the graft and approximate any loose tissue. Currently, it is not clear which specific protocol among ARP techniques has a superior impact on implant outcomes (Mardas et al. 2015). The most recent studies use xenograft or various compositions of allograft bone. Different membranes have been successfully employed. However, when considering the variety of surgical protocols used to perform ARP, very little information exists in the literature about the effects of suturing technique to secure the graft and approximate the tissues. Conventional socket suturing technique usually involves a horizontal mattress suture, crossing to form an external crossing shape over the top of the grafted socket. That suture technique will hereafter be called the external crossing suture. In some published studies, several simple interrupted sutures or continuous suture have been used to form a meshwork over the socket. Others have used various combinations of simple interrupted and horizontal mattress techniques. Still others have sutured the membrane to the tissue directly, rather than tying suture over the top. The authors of these studies did not emphasize or make specific reference to the suture

technique, but these differences are seen in their clinical photos (Iasella JM 2003; Beck and Mealey 2010; Barone et al. 2014; Walker et al. 2017). While different suturing techniques may accomplish the same goal of graft retention, they have different tension vectors on the surrounding soft tissue which may influence healing. As the buccal tissues are usually most vulnerable to remodeling loss, any technique modification that can preserve more buccal tissue may be clinically significant.

Internal Crossing Suture

A proof-of-concept clinical trial was recently conducted to compare conventional suturing techniques for ARP with one of the alternate techniques (fig. 1), an internal crossing suture (Park et al. 2016). This technique was first published in the medical literature by plastic surgeons demonstrating a way to achieve an esthetic skin closure (Gomes et al. 2012). Park and colleagues then adapted the concept and aimed to demonstrate the ability of the internal crossing suture to improve the results of ARP, by preserving a greater width of keratinized tissue and greater bucco-lingual width of the alveolar ridge of bone. This was reportedly accomplished by internal crossing suture shifting the suture tension vectors from a bucco-lingual direction to a mesio-distal direction, allowing the buccal soft tissue to relax while still stabilizing the graft. In the current study, the author's experience was that the internal crossing suture was a slightly more complex technique and took a few moments of additional time to complete compared to the external crossing suture. The primary outcome of the Park study was to evaluate the width of KT, measuring the shift in the MGJ. The secondary outcome considered changes in alveolar ridge dimensions. Their ARP protocol including grafting with bovine particulate xenograft bone and retaining the graft with a double-layer porcine collagen membrane. No attempt was made to obtain primary closure to

avoid the aforementioned unfavorable soft tissue changes associated with reflecting and repositioning a flap of buccal soft tissue. All patients' sockets healed without complications and implants were placed four months later.

At the time of surgery, the external crossing suture shifted the MGJ line in the linguo-coronal direction by a mean of 1.56 mm and the internal crossing suture allowed expansion of the MGJ line 0.25mm in the bucco-apical direction. After four months of healing from the tooth extraction, both groups experienced a mean reduction of KT width. The internal crossing suture group lost significantly ($p=0.007$) less (1.05 mm) KT compared to the external crossing group (2.83 mm). The internal crossing group also experienced less vertical and horizontal bone loss than external crossing group, but differences were only statistically significant at mid-crestal measurements and at the most coronal third of the ridge. The Park study results corroborated findings that open healing approach can successfully prepare the site for implant placement. They also reported that the suturing technique used can significantly affect the amount of bone and KT loss during wound healing (Park et al. 2016). The Park et al. study, at the time of this writing, was the only published study evaluating suture technique for ARP. The Park study was by a sample size of only 7 subjects per group, and that it only evaluated molar sites. Their study did not account for the impact on the ARP procedure on tooth sites in the esthetic zone, namely premolar and anterior teeth. Other studies have found that ridge resorption following tooth extraction is often more extensive in the esthetic zone, compared to molar sites which tend to have thicker buccal plates of bone (Schropp 2003).

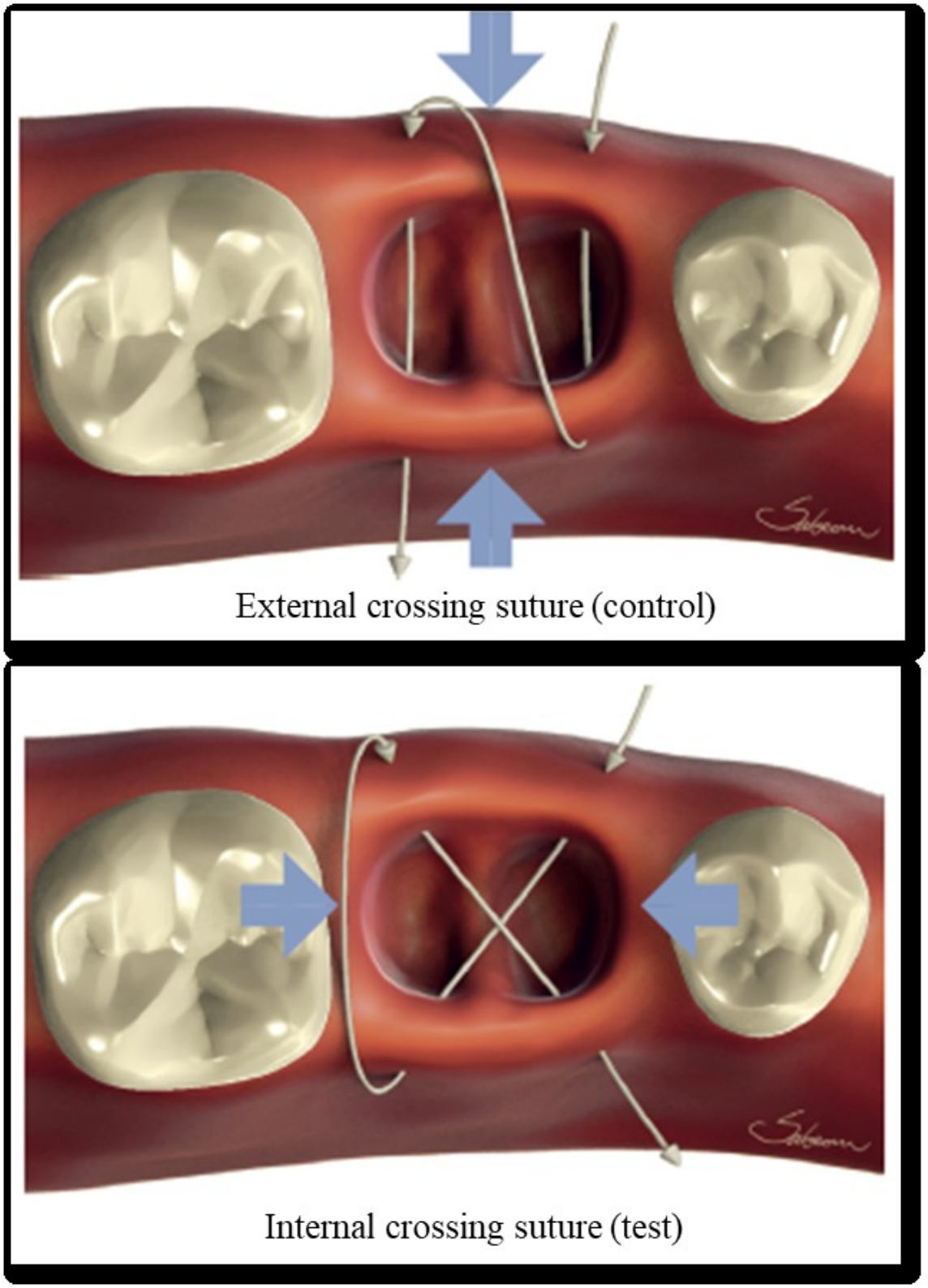

Figure 1. External (A) and internal (B) crossing sutures, edited from (Park et al. 2016)

Problem Statement

The purpose of this study was to evaluate how two suturing techniques affect the healing morphology of hard and soft tissue following alveolar ridge preservation procedure. This project will evaluate results using premolar and anterior tooth sites that make up the esthetic zone.

Hypotheses

1. The external crossing and internal crossing suture groups will differ significantly on width of alveolar bone after 15 weeks healing.
2. The external crossing and internal crossing suture groups will differ significantly on height of alveolar bone after 15 weeks healing.
3. The external crossing and internal crossing suture groups will differ significantly on width of keratinized tissue after 15 weeks healing.

CHAPTER 2

MATERIALS AND METHODS

Surgical Protocol

The surgical protocol in this study was the standard care rendered to all patients, regardless of study participation. Study participants simply volunteered to have measurements taken in addition to their standard treatment. The standard alveolar ridge preservation procedure following tooth extraction includes: atraumatic tooth extraction, socket degranulation and irrigation, placement of particulate bone allograft into the socket, coverage of the graft with a membrane, and then suturing to secure the membrane and tissue over the graft. Clinical photos were taken of the mouth of all patients, per standard of care protocol in periodontics.

Immediately after tooth extraction, the final decision about study enrollment was made based on having an alveolar socket with four walls with >50% remaining bone. Treatment was rendered per the standard of care irrespective of the remaining bone. Study participants were randomly assigned via computer-generated randomization to one of two groups to receive an internal crossing or external crossing horizontal mattress suture. To blind the operator to treatment groups, allotment was emailed to the operator (J.T.) on the day of the procedure and opened from the clinical operatory computer at the final step of the procedure. The group assignment was not revealed to the operator until after bone graft and membrane were placed. The external crossing suture (Figure 1) was tied by taking a bite from the distobuccal gingiva, passing lingually across the socket to take another bite at the distolingual, returning to the buccal aspect and repeating similar bites through mesial tissue. The X was completed by tying the knot over the top of the socket. The internal crossing

suture (Figure 1) was tied by taking bites crossing the socket obliquely from distobuccal to mesiolingual, returning to the mesiobuccal and again crossing the socket obliquely from mesiobuccal to distolingual. The internal crossing crisscrossed in the socket apical to the gingival margins and the knot tied perpendicular to the arch at the distal aspect of the socket.

The following materials were used for all patients: Combination (70/30) bone allograft[1] was placed into the tooth socket, covered with non-resorbable Polytetrafluoroethylene (PTFE) membrane[2], and stabilized with non-resorbable PTFE suture[3]. The allograft mixture was cortical bone, composed of 70% mineralized and 30% demineralized freeze dried bone allograft from a single donor. These materials are all part of standard protocols for the alveolar ridge preservation procedure and were selected based on the abundance of the research supporting their use. Vacuum-formed ethylene vinyl acetate (EVA) stents[4] were fabricated for each patient to wear as a retainer during the healing phase. The space in the retainer previously occupied by the extracted tooth was filled with a composite provisional tooth crown material[5]. The purpose of the retainer was threefold: to provide an esthetic prosthesis for the missing tooth, to help cover and protect the surgical wound from tongue exploration and food abrasion, and to help minimize shifting of neighboring teeth during the healing phase.

[1] enCore® 70/30 Combination Allograft #C73100, Osteogenics Biomedical Inc., 4620 71st Street Bldg 78-79, Lubbock, TX 79424
[2] TXT-200 Singles #TXT1224, Osteogenics Biomedical Inc., 4620 71st Street Bldg 78-79, Lubbock, TX 79424
[3] CytoplastTM Sutures #CS-0618PREM, Osteogenics Biomedical Inc., 4620 71st Street Bldg 78-79, Lubbock, TX 79424
[4] Clear Vacuum Forming Material, Buffalo Dental MFG, 159 Lafayette Dr, Syosset, NY 11791
[5] Integrity, Dentsply Caulk, 38 West Clarke Ave, Milford, DE 19963

Patients were given a seven-day course of systemic antibiotics and chlorhexidine 0.12% oral rinse to use twice daily, per standard protocols. Post-operative pain was managed per standard protocols.

Patients returned per standard protocol for follow-up appointments at one and three weeks to evaluate immediate healing after the procedure, manage any potential complications, and to remove sutures and membrane at approximately three weeks. The PTFE membrane was removed at three weeks, per manufacturer recommendation. Patient were scheduled to return after 15-weeks to take final measurements. The area was anesthetized with local anesthetic and transgingival probing was repeated by passing an endodontic file through the measuring stent. Upon exiting the study, some patients, who had already been approved by the school of dentistry implant committee, received a dental implant at the edentulous study site.

Subject Recruitment

Potential study subjects were recruited from patients who were undergoing tooth extraction procedures as described in the previous Surgical Protocol section. Subjects were recruited from the patient pool within the UMKC School of Dentistry via email announcements and flyers posted on official bulletin boards. Potential subjects presented to the UMKC Advanced Periodontics clinic for a limited exam to determine if they qualified for the study. Participants reviewed and signed a written informed consent approved by the Institutional Review Board (IRB). It stated that study participation was optional and explained any potential risks associated with participating in this research study.

Qualifying participants were adults with a permanent non-molar tooth requiring extraction. Female participants were not pregnant or trying to become pregnant. Participants

with poorly-controlled chronic disease were excluded. Participants did not have any medical condition or take medication that would adversely affect bone healing (e.g. head and neck radiation or bisphosphonate chemotherapy). Only non-smokers and light smokers were included, meaning less than ten cigarettes per day. After the tooth extraction procedure, qualifying patients had four walls of bone surrounding the socket without any buccal dehiscence exceeding 50% of the height of the buccal wall. Qualifying patients received tooth extraction and ARP treatment at no charge. Patients that volunteered, but did not qualify for the study will received the same standard of care treatment, paying only the cost of materials used, approximately $219.

For this pilot study, a sample size of convenience was used, with N=20 subjects if possible. Eligible patients were enrolled during the approximate period of August 2018 through November 2019, to allow for healing time, data analysis, and thesis defense before graduation.

Measurement Protocol

Enrolled subjects were evaluated for study variables at baseline (just after tooth extraction) and approximately 15 weeks later when hard and soft tissue healing was considered complete and suitable to receive a dental implant. Prior to the tooth extraction appointment, alginate impressions of the relevant dental arch was made and a stone cast created to fabricate custom ethylene vinyl acetate (EVA) stents. Stents were used to standardize and achieve reliable measurements at baseline and again after 15-weeks healing. Three stents were fabricated: first for alveolar ridge width measurements, second for alveolar ridge height and keratinized tissue width measurements, and third as a vacuum-formed retainer to fill the gap left by the missing tooth. See Appendix 1 for the measurement stent

fabrication procedure. Holes were drilled into the stents to perform baseline and final measurements. The stents were trimmed for convenient placement in the mouth. They extended to cover at least two neighboring teeth to lock stent into position for reliable measurements. Alveolar ridge measurements were accomplished by bone sounding with a size 20 endodontic file with rubber stopper. The measuring technique included bone sounding with the endodontic file to eliminate variations in soft tissue thickness and consistently quantify dimensions of alveolar bone. The stopper position was measured outside the mouth with a digital caliper to maximize precision. Each measurement was repeated three times to generate a mean measurement to ensure precision. Stent measurement photos may be found in Appendix 1.

Alveolar ridge width was measured according to the following protocol. Reference holes were drilled into the stent on midbuccal and midlingual aspects corresponding to height of the alveolar crest of bone. A single measuring hole was placed on both midbuccal and midlingual sides, located 3 mm apical to each reference hole. Alveolar ridge width was measured at the buccal, middle, and lingual portions of the crest of the ridge and centered mesiodistally. Ridge height measurement was accomplished by drilling two holes in the coronal portion of the second stent: one each at the midbuccal and midlingual, respectively. Then a vertical distance from stent to bony crest was measured. The second stent was also used to measure keratinized tissue changes per the position of the mucogingival junction (MGJ). The MGJ was marked with a hole in the stent on midbuccal aspect and for mandibular teeth also on the midlingual aspect. Then the final MGJ position after the 15 week healing period was compared to the original pre-healing reference hole and any change measured with the file and stopper and then caliper.

Experimental Design

The following variables were calculated from measurements taken at baseline and after approximately 15 weeks of healing: change in alveolar ridge width, change in alveolar ridge height at the buccal, middle, and lingual aspects of the ridge, and change in buccal MGJ position. A sample size of convenience was proposed, seeking 20 subjects for N=10 subjects per treatment group.

TABLE 1

EXPERIMENTAL DESIGN

Independent Variable	Dependent Variables				
Treatment Group (N =10 subjects/group)	Alveolar ridge buccal height loss (mm)	Alveolar ridge lingual height loss (mm)	Alveolar ridge buccal width loss (mm)	Alveolar ridge lingual width loss (mm)	Keratinized tissue width change: coronal migration buccal MGJ (mm)
External crossing suture (Control)					
Internal crossing suture (Test)					

Data Analysis

Descriptive statistics were calculated. The change in alveolar width, and height on buccal and lingual aspects and keratinized tissue width were evaluated as a function of suture type via individual 1-Factor ANOVAs including a measure of effect size or a two-sample t-

test were performed for the variables. All statistical evaluations were done using a statistical software program[6] with significance set at 0.05.

[6] SPSS Statistics 23, IBM Corp, Armonk, NY 10504

CHAPTER 3

RESULTS

Eleven patients, 4 males and 7 females aged 32 to 75 (mean age 52) met the inclusion criteria and were enrolled in the study. All subjects who enrolled in the study were able to complete the study. With the eleven enrolled subjects, twelve teeth met the indications for extraction, crown and/or root fracture associated with dental caries and/or malocclusion. None of the teeth were extracted because of chronic periodontal disease with associated horizontal bone loss. All patients who entered the study met the final intraoperative inclusion criteria, having a bony socket with four walls, with at least 50% remaining height of the buccal wall. All sites were bordered by natural teeth mesially and distally except one case, where tooth #4 and tooth #5 were sequentially extracted and grafted on the same patient. This patient completed the study with tooth #4 and then re-entered the study for tooth #5. All enrolled subjects healed from the tooth extraction and alveolar ridge preservation procedure without signs of infection or other complications. All membranes were removed at three weeks after tooth extraction except two were removed at two weeks – one due to the patient's travel schedule and another became loose and was removed at 16 days. Both subjects with early membrane removal were in the test group, and this small departure from protocol may have had some influence on the comparative results, but it would be difficult to quantify. The majority of sites (9/12) were in the maxilla, and between both jaws included 11 premolars, and one maxillary lateral incisor. Figure 3 includes photographic images of a representative tooth that was extracted, sutured using external crossing technique, through the 15-week healing phase, while Figure 4 includes a similar set of photographic images with the internal crossing technique.

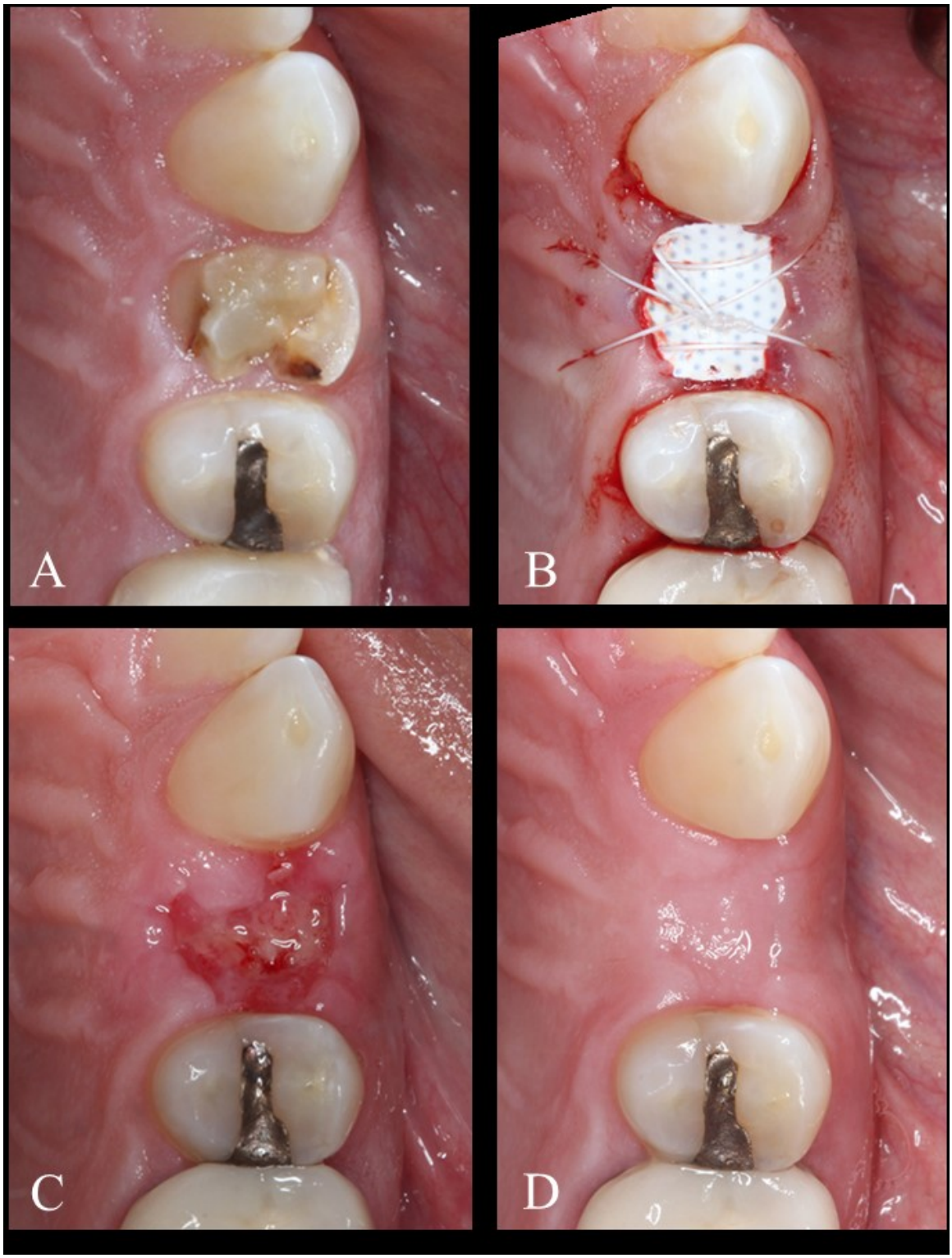

Figure 2. Alveolar ridge preservation (control). A. Fractured tooth #12. B. Membrane placed over bone graft and sutured with external crossing horizontal mattress. C. Membrane removal at 3 weeks. D. Site healing after 15 weeks.

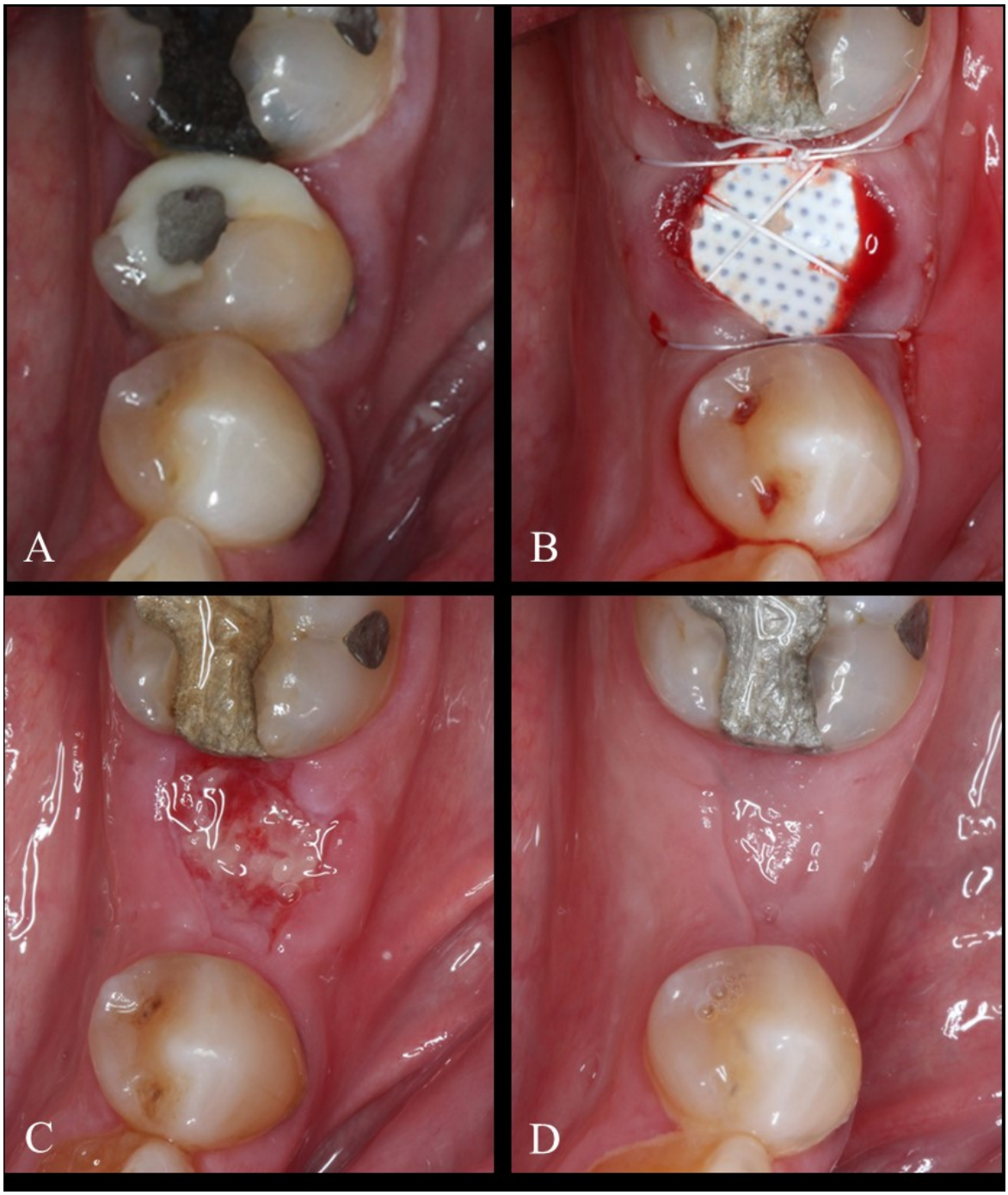

Figure 3. Alveolar ridge preservation (test). A. Non-restorable tooth #20. B. Membrane placed over bone graft and sutured with internal crossing horizontal mattress.
C. Membrane removal at 3 weeks. D. Site healing after 15 weeks

Individual subject measurements for alveolar ridge measurement changes and keratinized tissue width measurement changes are presented in Tables 2 and 3, respectively; while overall results, means and standard deviation values for the treatment groups, for those same respective measurements are presented in Tables 4 and 5.

TABLE 2

ALVEOLAR RIDGE CHANGES: INDIVIDUAL SUBJECT RESULTS

Subject	Tooth #	Group	Buccal height	Lingual height	Buccal width	Lingual width
1	13	External	0.59	0.75	0.42	-0.21
2	13	Internal	-2.18	1.91	-0.56	-0.14
3	7	External	1.42	1.46	-0.66	-2.39
4	4	Internal	0.37	0.55	0.45	-0.43
5a	4	Internal	-0.86	0.60	-0.18	-1.54
5b	5	External	-0.88	-2.76	1.06	-2.70
6	13	Internal	-3.28	-2.43	-4.39	0.02
7	12	External	-0.96	-2.26	-5.09	-1.46
8	20	External	0.27	-0.89	-0.51	-1.25
9	12	Internal	-4.16	-2.58	-0.27	-0.22
10	20	External	-0.85	-1.29	-1.30	-1.48
11	20	Internal	-1.28	-0.97	-1.17	-0.62
Mean			-0.98	-0.66	-1.02	-1.04
St Dev			1.54	1.59	1.79	0.87

TABLE 3

KERATINIZED TISSUE WIDTH CHANGES

Buccal Mucogingival Junction				
Subject	Tooth #	Group	Position (mm)	Change
1	13	External	0.00	none
2	13	Internal	-0.30	KT loss
3	7	External	0.23	KT gain
4	4	Internal	0.00	none
5a	4	Internal	-0.57	KT loss
5b	5	External	-0.37	KT loss
6	13	Internal	-1.05	KT loss
7	12	External	-0.69	KT loss
8	20	External	-0.37	KT loss
9	12	Internal	1.61	KT gain
10	20	External	0.00	none
11	20	Internal	0.00	none
	Mean		-0.13	KT loss
	St Dev		0.63	

TABLE 4

ALVEOLAR RIDGE CHANGES BY GROUP

Independent Variables	Dependent Variables			
Treatment Group (N =6 subjects/group)	Buccal height (mm)	Lingual height (mm)	Buccal width (mm)	Lingual width (mm)
External crossing suture (Control)	-0.07 ±0.90	-0.83 ±1.51	-1.01 ±1.98	-1.58 ±0.81
Internal crossing suture (Test)	-1.90 ±1.51	-0.49 ± 1.65	-1.02 ±1.58	-0.51 ±0.52

TABLE 5

MUCOGINGIVAL JUNCTION POSITION CHANGE

Independent Variable	Dependent Variable	
Treatment Group (N =6 subjects/group)	Position Change (mm)	Clinical Result (mm)
External crossing suture (Control)	-0.20 ±0.31	Slight KT loss
Internal crossing suture (Test)	-0.05 ±0.83	Slight KT loss

Alveolar Bone Width

The mean alveolar buccal bone width decreased by -1.01 ±1.98 mm in the control group and -1.02 ±1.58 mm in the test group. The mean alveolar lingual bone width decreased by -1.58 ± 0.81 mm in the control group and -0.51 ±0.52 mm in the test group. With the test group, there was significantly less lingual width loss ($p = 0.03$) with an effect size of 38% based on the partial η^2 statistic.

Alveolar Bone Height

The mean alveolar buccal bone height decreased by -0.07 ±0.90 mm in the control group and -1.9 ±1.51 mm in the test group. The mean alveolar lingual bone height decreased by -0.83 ±1.51 mm in the control group and -0.49 ±1.65 mm in the test group. Using ANOVA, buccal height change was significantly different ($p=0.04$) with an effect size of 35% based on the partial η^2 statistic.

Keratinized Tissue Width

A coronal shift of the mucogingival junction was interpreted as a decrease in keratinized tissue, while an apical shift was considered an increase in keratinized tissue. The

buccal mucogingival junction shifted 0.20 ±0.31 mm coronally in the external (control) group and 0.05 ± 0.83 mm in the internal (test) group which were not statistically different ($p = 0.72$).

CHAPTER 4

DISCUSSION

To restore a missing tooth with a dental implant crown, there must be adequate alveolar bone volume, and bone in the right location, to restore function and esthetics with a good long-term prognosis. Alveolar ridge resorption following tooth extraction is a well-established phenomenon (Lam 1960; Atwood 1971). Approximately 50% of the alveolar ridge width may be lost within the first 12 months following single tooth extraction (Schropp L 2003).

Abundant research has shown that alveolar ridge preservation minimizes the bone loss experienced following extraction (Ten Heggeler et al. 2011). The minimum amount of keratinized tissue needed to sustain periodontal health is disputed, and there may be no minimum, in the absence of plaque and inflammation (Kim and Neiva 2015). However, several systematic reviews have concluded that keratinized tissue is essential for peri-implant health (Gobbato et al. 2013; Lin et al. 2013; Brito et al. 2014). Additional studies have shown that the best preservation of bone and keratinized tissues following tooth extraction occurs with minimal flap elevation and when a bone graft is placed and covered with an exclusionary membrane that remains exposed without primary closure (Engler-Hamm et al. 2011; Barone et al. 2013; Barone et al. 2014; Park et al. 2016; Hong et al. 2019).

Clinically, the change in alveolar bone width is more relevant than change in height. This is especially true in the esthetic zone, where dental implants are placed subcrestally, and the most common bone deficiency is on the facial (buccal) aspect (Huynh-Ba et al. 2010; Chappuis et al. 2013; Chappuis et al. 2017). In the current study, the change in total alveolar bone width was not a parameter specifically measured. Total width change may roughly be

inferred by combining individual buccal and lingual measurements, suggesting a range from a loss of 5.09 mm to a gain of 1.06 mm. The inferred total mean loss of alveolar width was comparable to pooled results in a meta-analysis of alveolar ridge preservation (Avila-Ortiz et al. 2019). Both the external (control) and internal (test) suture groups demonstrated that ARP was an effective treatment to decrease ridge width loss after extraction. In terms of change in alveolar bone height, in the current study ranged from a loss of 4.16 mm to a gain of 1.91 mm, which is also comparable to the pooled mean loss of alveolar height in a meta-analysis of alveolar ridge preservation (Avila-Ortiz et al. 2019).

A change of large magnitude was not expected in the keratinized tissue width, given the surgical protocol of minimal flap reflection and no flap advancement. The Park study found a statistically significant difference between groups: that the external suture group lost a mean of 1.56±0.90mm KT while the internal suture group actually increased keratinized width by 0.25±0.66mm. However, the present study found a clinically insignificant loss of KT in both groups, which were not different statistically different from each other.

The suturing techniques employed to secure the bone graft and membrane during alveolar ridge preservation are manifold in clinical practice and throughout the available literature. When suture technique has been reported in an alveolar ridge preservation study, it is simply documented in the study methods section. In many cases, the specific technique is not elucidated. Data comparing the effects of suture technique on healing results are scarce. This study evaluated suture technique as the independent variable to quantify any resultant differences in bone and keratinized tissue preservation.

Non-molar teeth sites were chosen for evaluation in this study because the first and only study published about these suture techniques for ARP evaluated only molar tooth sites

(Park et al. 2016). It would be expected to find less alveolar bone loss in both test and control groups of the Park study compared to this study based on the region of the mouth in the inclusion criteria (Katranji et al. 2007; Huynh-Ba et al. 2010; Chappuis et al. 2013; Temple et al. 2016). Any non-molar tooth site was eligible for inclusion in this study, however, the subjects who enrolled presented predominately premolar sites (11/12) with only one maxillary lateral incisor. Nine sites (75%) were in the maxilla and only three (25%) of sites were in the mandible.

This study differed in materials used for ARP from the Park study. In the Park protocol, the socket was filled with bovine xenograft bone suspended in a 10% collagen matrix because it is considered more dimensionally stable than allograft. The bone was covered with a double layer of resorbable collagen membrane – so no membrane removal was necessary. In this study, a PTFE membrane was chosen in case different patient's oral enzymes resorbed a collagen membrane at different rates. The membrane removal after three weeks was the manufacturer's recommended minimum time and there is a possibility that the healing results may have been slightly different if the membrane remained in place longer than three weeks. The three-week interval was chosen because a non-resorbable membrane eventually starts to collect plaque biofilm and requires attentive cleaning by the patient.

In the current study, no subjects were lost to follow-up, although several subjects exited the study at 17-18 weeks post-operatively instead of 15 weeks, because they cancelled their appointments and were encouraged to reschedule to complete the study. Although the additional healing time might increase variability, it was not expected to be clinically significant. Two subjects in the test group had their membranes removed at two weeks instead of the three weeks healing protocol and they both lost some bone graft material at that

time. There first subject had a travel conflict and the second subject reported that the membrane came lose after two weeks. Part of the study protocol including fabricating a passive vacuum-formed retainer to protect the site during healing. However, most subjects reported not wearing it consistently or at all, because they reported having no pain and they thought it was inconvenient and unnecessary.

Clinical Implications

Both the external and internal suture groups demonstrated that ARP was an effective treatment to decrease ridge width loss after tooth extraction. In the internal suture (test) group, there was significantly less lingual alveolar width loss than in the external suture (control) group. In addition, the lingual width effect size (partial $\eta^2 = 0.38$) may suggest clinical relevance as well as statistical significance.

As already mentioned, loss of alveolar bone width is a clinically relevant issue especially in the esthetic zone where facial (buccal) bone deficiencies often occur with implant placement (Huynh-Ba et al. 2010; Chappuis et al. 2013; Chappuis et al. 2017). In the current study, while there was significantly lower lingual alveolar width change with the internal suture technique, there was no significant difference between external or internal sutures in relation to buccal alveolar width change. If buccal bone width change is more clinically relevant, then based on the current results, it does not appear that one suture type would be preferred over the other in terms of subsequent buccal bone width change in relation to non-molar tooth extraction sites evaluated in this study. However, because of some limitations of the current study bone measurement protocol, the results and implications might be different using another evaluation technique that will be addressed in the following sections.

For keratinized tissue width, a change of large magnitude was not expected, given the surgical protocol of minimal flap reflection and no flap advancement. Both suture groups experienced a clinically insignificant loss of KT, which were not statistically different from each other, so again, neither suture type would be preferred for managing KT loss.

Study Limitations

As with any study, there always study limitations that must be considered. For this study, there are several aspects addressed in the following section.

Care was taken to perform each surgery as consistently as possible, but the operator in this study was a resident training in an advanced education program and thus, the results may have been affected by limited surgical experience.

Changes in the mucogingival junction were largely subtle and smaller than the precision attainable marking the tissue with an endodontic file through a 1mm diameter hole in a semi-flexible measuring stent. There is also a level of subjectivity visually determining the exact location where the keratinized tissue ends and mucosa begins. More precise measuring of the mucogingival junction position might be obtained with the aid of histochemical staining using Lugol's iodine solution, although a previous study failed to detect a significant difference between visual inspection and the staining method (Guglielmoni et al. 2001).

Regarding buccal and lingual alveolar bone measurements, both baseline and final measurements were taken through the same 1mm diameter hole in the measuring stent. Despite that approach, minor changes in angulation of the file and its effect on measurement results is unknown. With the current study bone measurement protocol, it was not possible to measure the actual thickness of the buccal plate of bone, but buccal plate thickness

significantly influences the dimensional change of the alveolar ridge during healing, especially in the non-molar or esthetic zone (Chappuis et al. 2013; Chappuis et al. 2017). The buccal plate is thinner in the non-molar zone in both jaws (Katranji et al. 2007) and thus more susceptible to resorption after tooth extraction. A buccal bone thickness of ≤1mm has been identified as a critical factor associated with the extent of bone resorption. While it may be tempting in this study to infer total ridge width change from individual buccal and lingual measurements, this may introduce more potential error and be invalid. Typically, CBCT imaging would be used to adjust for buccal bone thickness as a confounding variable (Zhang et al. 2015).

It may be possible to record more precise changes in alveolar bone height and width using a pre-extraction and post-healing CBCT scan with a radiographic stent for positional reference. Nonetheless, in this study, clinical measurements were done, because only a single CBCT scan was authorized for subsequent dental implant planning after healing.

Study subjects were recruited from among the patients of record at UMKC School of Dentistry. As is typically the case with a pilot study, a sample size of convenience was used, which is especially reasonable considering that the PI was an Advanced Periodontics resident.

Future Investigations

Future studies using CBCT to evaluate total alveolar ridge width changes with a larger subject sample size may reveal more compelling results. In a future study, the total ridge width change could be evaluated comparing authorized CBCT images taken before and after the ARP procedure using varying suture techniques. Future studies should quantify the thickness of the buccal plate of bone to adjust for its influence on bone resorption during

healing, which may at times be more clinically significant than the suturing method employed.

In terms of sample size for a future study, multiple ARP studies from the same research group have achieved adequate power for histomorphometric analysis of bone with approximately 20-25 patients per randomized group (Beck and Mealey 2010; Wood and Mealey 2012; Eskow and Mealey 2014; Borg and Mealey 2015; Whetman and Mealey 2016; Demetter et al. 2017; Walker et al. 2017).

CHAPTER 5

CONCLUSIONS

Comparing baseline measurements to measurements after at least 15-weeks healing:

1. The internal crossing suture group (test) performed significantly better on lingual width of alveolar bone. There was no significant difference between groups on buccal width of alveolar bone.
2. The external crossing suture group (control) performed significantly on buccal height of alveolar bone. There was no significant difference between groups on lingual height of alveolar bone.
3. The external crossing and internal crossing suture groups did not differ significantly on width of keratinized tissue.

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APPENDIX 1

FABRICATION OF MEASURING STENTS

Prior to tooth extraction, a full arch impression was taken with a plastic dental tray and alginate material in the subject's mouth. The impression was disinfected with spray disinfectant. A cast of the dental arch was poured using dental stone. After approximately 45 minutes curing the impression was removed from the stone and excess stone trimmed away for convenience. Three vacuum-formed molds of the dental arch were fabricated from the stone cast from heated sheets of ethylene vinyl acetate (EVA). Two molds were trimmed down to 1-2 neighboring teeth to become the measurement stents. This is for convenient placement and removal from the cast and from the subject's mouth. The third mold was trimmed for practical insertion and removal from the mouth. Separate stents were used to measure alveolar ridge dimensions and MGJ position. Measurement holes were drilled through the stents while positioned on the cast using a dental handpiece and small round bur. The gingival margin position was marked with holes on the buccal and lingual aspects, and centered mesiodistally. Three holes were drilled into the occlusal surface of the stent for bone height measurements at the buccal, middle, and lingual aspects of the alveolar ridge. The position of the buccal MGJ was marked with a measurement hole on the second stent. The stents were disinfected with spray and rinsed with water before and after placement into the subject's mouth.

Essix type retainers for the subject to wear post-operatively were fabricated by the same technique. A final additional step included filling the space on the stent previously occupied by the extracted tooth with provisional tooth crown material.

Figure 4. Stone cast (C) fabrication from alginate impression (A) and dental stone (B).

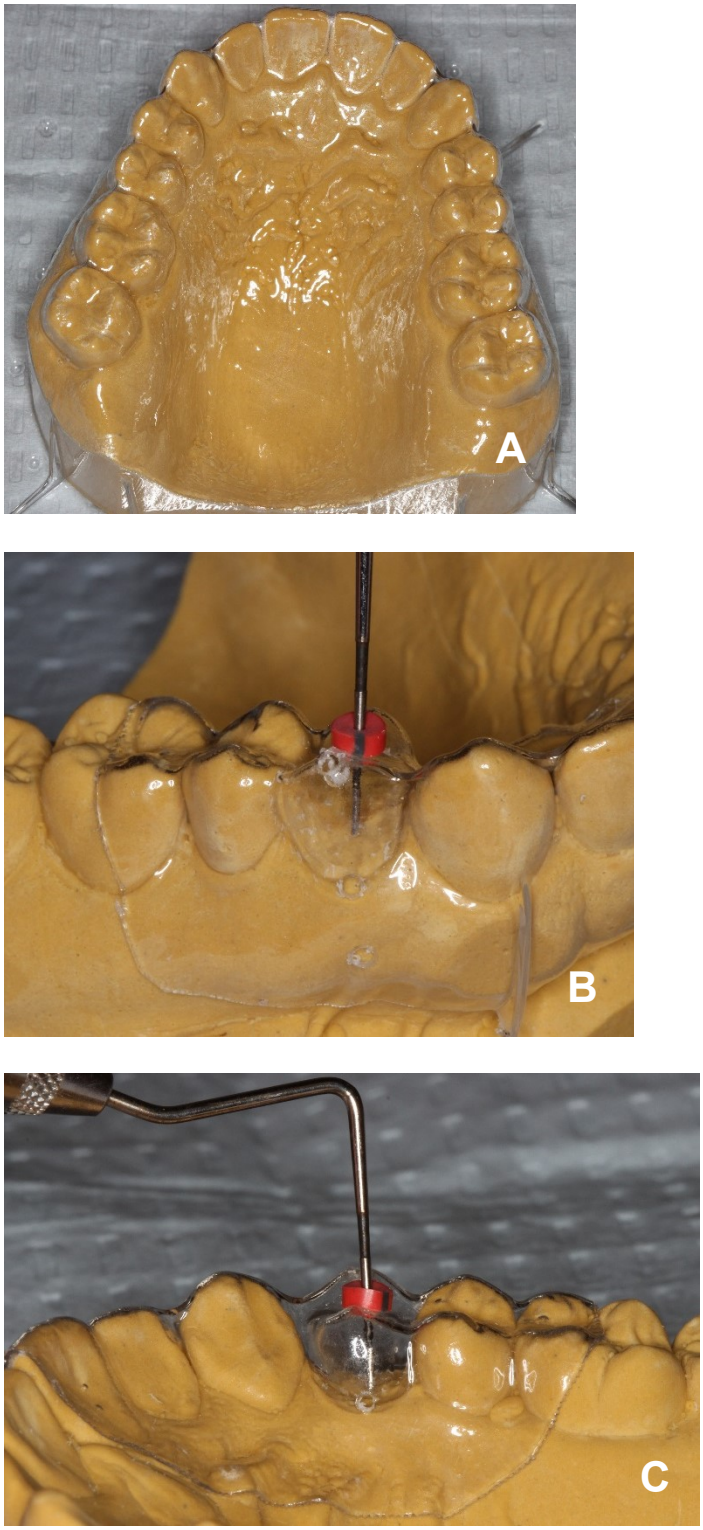

Figure 5. Vacuum-formed EVA mold (A) and measurement stent buccal view (B) and lingual view (C)

APPENDIX 2

CLINICAL MEASUREMENT PROTOCOL

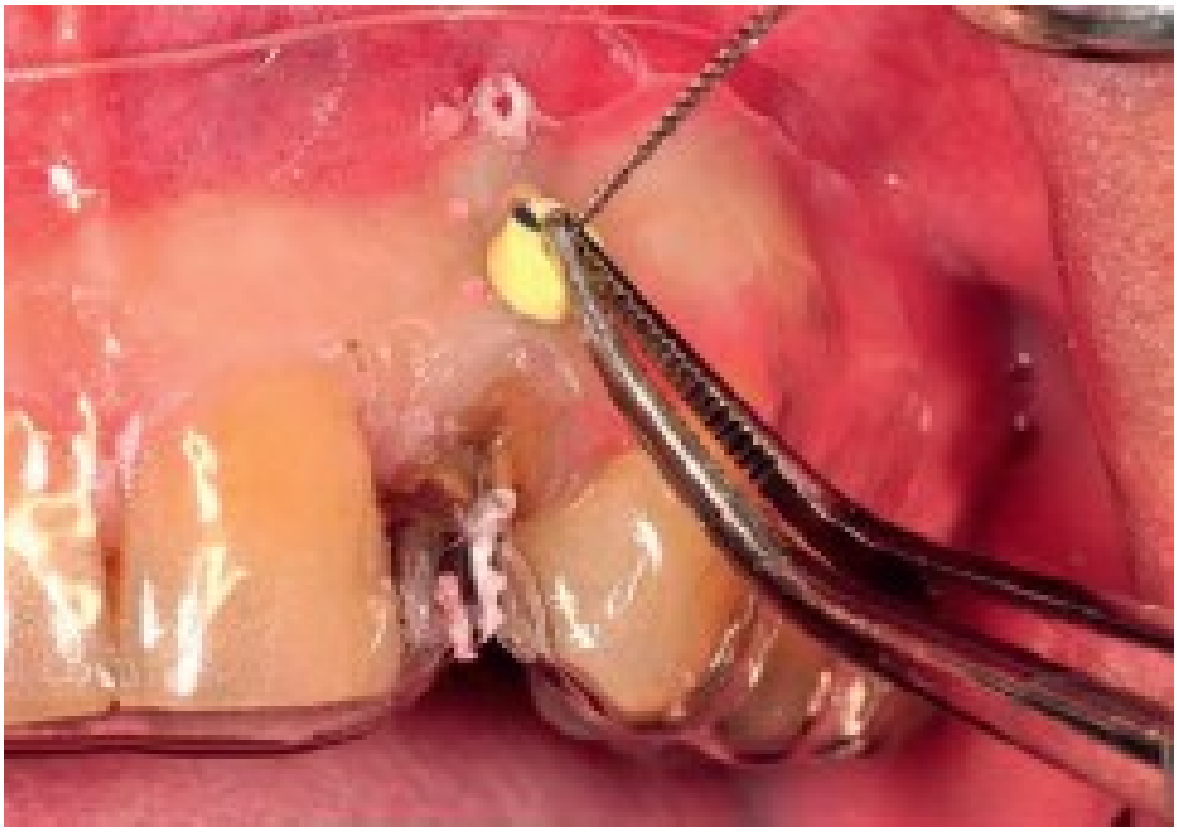

Figure 6. Example intraoral alveolar ridge measurement (Parashis et al. 2016)

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Zhang W, **Tullis J**, Weltman R, Cone Beam Computerized Tomography (CBCT) Measurement of Alveolar Ridge at Posterior Mandible for Implant Graft Estimation. Journal Oral Implantology. 2015 Dec;41(6):e231-7.