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RIDGE PRESERVATION: EVALUATION OF KERATINIZED TISSUE WIDTH

by

Daniel Brockway, DMD

Thesis submitted to the Faculty of the
US Army Advanced Education in Periodontics Graduate Program
Uniformed Services University of the Health Sciences
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THESIS APPROVAL SHEET

Ridge Preservation: Evaluation of Keratinized Tissue Width

This thesis is submitted by Daniel Brockway and has been examined and approved by an appointed committee of the faculty of the Uniformed Services University of the Health Sciences.

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ABSTRACT

Ridge Preservation: Evaluation of Keratinized Tissue Width:

Brockway, MS Oral Biology, 2020

Thesis directed by: MAJ Jennette O'Bryhim, Assistant Director, U.S. Army Advanced Education Program in Periodontics

This single-blind, randomized clinical trial compared four different ridge perseveration techniques immediately following single tooth extraction in eighty-two patients. Eligible patients were randomized into four treatment groups:

(1) Freeze dried bone allograft (FDBA) contained with a dense polytetrafluoroethylene (Cytoplast) membrane

(2) FDBA contained with a Cytoplast membrane with a buccal onlay graft

(3) FDBA contained with a human amniotic-tissue derived membrane (BioXclude)

(4) FDBA contained with BioXclude with a buccal onlay graft

While a myriad of investigative goals were compared in this clinical trial, the primary dependent variable of this project was the preservation of the buccal keratinized tissue width at the extraction site. The initial buccal keratinized tissue width was measured with a periodontal probe prior to the extraction of the tooth. Following four

months of healing after ridge preservation, the buccal keratinized tissue width was measured again at the time of dental implant placement.

The results of this study suggest that all four ridge preservation treatment groups were equally effective in preserving the baseline buccal keratinized tissue width at the time of tooth extraction. There was not a statistically significant difference to indicate that any one ridge preservation technique was superior in preserving the amount of keratinized tissue width.

Cytoplast and BioXclude are both effective membranes in the preservation of the buccal keratinized tissue width when used in combination with FDBA when performing ridge preservation. The buccal keratinized tissue width is also preserved when an additional buccal onlay graft is used in the ridge preservation technique.

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STATEMENT OF THE PROBLEM

Dental implants are a staple in modern dentistry for the rehabilitation of partial and complete edentulism. Their widespread use is made evident by the inclusion of the "Peri-Implant Diseases and Conditions" diagnosis portion of the updated 2017 World Workshop proceedings[1]. Hard and soft-tissue deficiencies, one of the new diagnoses, can complicate the placement of dental implants in addition to threatening their long-term success[2].

The etiologies of hard tissue deficiencies of the alveolus include root fractures, endodontic infections, periodontitis, and tooth loss. According to the 2017 World Workshop proceedings, there is a high level of evidence concerning the loss of alveolar bone following exodontia, especially if the tooth is removed traumatically[2]. Therefore, ridge preservation techniques are utilized following exodontia to minimize this seemingly unavoidable loss of hard tissue[3].

The etiologies of soft tissue deficiencies of the alveolus are predominately from periodontitis and tooth loss. The volume of hard tissue supports the overlying soft tissue, making these two components intimately related. Thus, preserving the hard tissue volume with ridge preservation techniques is vital in preserving the soft tissue contours[3].

Keratinized tissue is one characteristic of the soft tissue that is important to preserve when a patient is treatment planned for a dental implant following exodontia. It is thought to be favorable around implants to improve long-term health and maintenance of the surrounding periodontium. The minimum amount of keratinized tissue width

around an implant is a controversial topic[4], however, it has been suggested that maintaining a minimum of two millimeters of keratinized tissue is an appropriate goal, in order to limit patient discomfort and plaque retention[5]. Thus, a ridge preservation technique should also preserve tissue characteristics and volume in addition to the hard tissue.

CHAPTER 2: Background

Modern implant dentistry has evolved as the treatment option of choice to rehabilitate fully and partially edentulous patients back to a functional, comfortable, and esthetic dentition[6]. Alveolar bone resorption and the loss of soft tissue volume following exodontia is inevitable[7]. Depending on the degree of subsequent ridge deficiency, implant placement can be challenging.

SOCKET HEALING

Wound healing of the dental extraction socket is a well-studied physiologic process. Classically described by Amler in 1969 through a study of human histology, the healing of the extraction socket is initiated with the creation of a blood clot. Within the first week, granulation tissue replaces the blood clot and epithelial cells commence their propagation over the socket. After one week, the reparative milieu is composed of granulation tissue, connective tissue, epithelium, and the formation of osteoid at the base of the extraction socket. At three weeks, the healing socket is entirely covered with epithelium and mineralization of the osteoid is noted. Bone formation can be appreciated at the six week timepoint[8].

In the process of modeling and remodeling after tooth extraction, alveolar hard and soft tissue volume loss is expected[9]. This can be attributed to an upregulation of osteoclastic activity that causes resorption of the socket walls[10]. Up to half of the width of the edentulous ridge can resorb during the first year, with the majority of this loss occurring during the first three months[11]. While alveolar vertical loss ranges from 11-

22% from baseline, a significant horizontal decrease up to 63% from baseline, creates the largest obstacle to optimal implant placement[12]. This deleterious phenomena generally requires surgical intervention in the form of ridge preservation, guided bone regeneration, and/or soft tissue augmentation in order to achieve favorable clinical parameters for endosseous implant placement.

The degree of change in the alveolar process after an extraction is dependent on many aspects. Genetic elements that determine site-specific anatomy can predispose the alveolar process to more severe resorption following exodontia. Morphologic characteristics are determined by the size of the tooth in relation to the width of the bony housing and its inclination in the dental arch. These variations in tooth size and eruption pattern can lead to a thin buccal cortical plate, dehiscence, or fenestration[13]. Araujo demonstrated that bone loss predominately occurs on the buccal surface. Histologically, he describes the buccal bundle bone as a tooth-dependent structure, implying its propensity to resorb following tooth removal, especially when the buccal cortical plate is already thin[14].

Surgical technique also influences socket healing. Atraumatic extraction methods reduce alveolar bone loss by minimizing trauma to the cortical plates. Extraction techniques using elevators and forceps increase the occurrence of damage to the socket walls. For this reason, periotomes or vertical extraction techniques are recommended to avoid damaging the fragile buccal cortical plate through horizontal forces[15]. Sectioning multi-rooted teeth can also aid in minimizing extraction forces. Patients subjected to traumatic extractions often are poor candidates to receive dental implants without additional grafting techniques[16].

RIDGE PRESERVATION

Ridge preservation is a general term for varying surgical protocols that aid in preserving the volume of the edentulous ridge following exodontia. Atraumatic extraction techniques, bone grafting materials placed in the extraction socket, and a barrier to contain the graft and exclude soft tissue are the principle components of the procedure[17]. Ridge preservation continues to garner attention from clinical researchers to better understand which combination of materials and methods improve the quantity and quality of bone and soft tissue. While it is rarely possible to preserve all of the pre-extraction alveolar ridge volume, it is commonly accepted that ridge preservation mitigates the degree of loss[18]. In a systematic review of alveolar ridge preservation, Stumbras concluded that there is no gold standard established for maximizing clinical benefits through a specific ridge preservation technique[3].

Bone grafting materials contribute to the success of ridge preservation, through osteoconduction, in which they maintain space, support the soft tissue, and act as a scaffold to facilitate angiogenesis and the influx of bone progenitor cells. These biomaterials can be placed in an extraction socket alone or in combination with a barrier membrane in order to preserve the quantity of the osseous structures. Autograft, allograft, xenograft, and alloplast have all demonstrated success in preservation of hard tissue volume followed by implant success. Autografted sites provide sufficient ridge preservation, allowing the placement of implants with a 98.3% 5-year success rate[19]. Ridge preservation with allograft versus extraction alone preserved 1.2mm ±0.9mm of horizontal alveolar bone[20]. Compared to extraction alone, xenografts reduce horizontal

resorption by 1.8mm[21]. Alloplast, while arguably an inferior option of the available grafting materials, also achieves ridge preservation that can support implant placement[22]. Currently, there is a lack of evidence to suggest which grafting material provides the best clinical results for the success of implants placed in ridge preserved sites.

Barrier membranes, categorized as either non-resorbable or resorbable, physically protect the socket and exclude bacterial, epithelial, and connective tissue cells, which in turn allows for the selective proliferation of osteogenic cells[23]. Barrier membranes successfully preserve ridges when used alone or in conjunction with bone grafting materials[20, 24]. Many resorbable membranes and expanded polytetrafluoroethylene require primary closure coverage by the soft tissue, requiring releasing incisions which adds surgical complexity and morbidity to the procedure[25]. Ridge preservation is simplified if barrier membranes are left exposed without the need of primary soft tissue closure. Clinical studies involving high-density polytetrafluoroethylene membranes left exposed to the oral environment during ridge preservations procedures have shown promising clinical results[26].

BARRIER MEMBRANES

High-density polytetrafluoroethylene (dPTFE) membranes are a frequently used non-resorbable membrane used in ridge preservation. They are impenetrable to bacteria because of their sub-micron pore size, allowing them to be placed without primary wound closure. Surgical complexity increases when preforming ridge preservation using a membrane that cannot be left exposed[27]. The main drawback of non-resorbable membranes is the need for retrieval, which requires a second procedure. For this reason, resorbable membranes are often preferred by clinicians.

Resorbable membranes can also be left exposed during ridge preservation. Membrane resorption prior to the completion of bone formation and an increase in soft tissue inflammation are their drawbacks[23]. Resorbable collagen was compared against dPTFE in a 2015 ridge preservation study. The authors concluded that both membranes when used with bone allograft material in ridge preservation reduced alveolar resorption. Both membranes yield similar clinical and histologic results[28]. Similarly, dPTFE and Alloderm (an allogeneic soft tissue graft) were also compared in a similar study that showed no histologic differences between the compared membranes[29].

BioXclude, made by Snoasis, is a resorbable multilayered dehydrated human amnion and chorion bioactive barrier. The manufacturer touts its superiority as a membrane because it contains over 250 growth factors and biologic mediators. It is suggested that the growth factors speed up wound healing, improve vascular growth, and reduce inflammation in the healing socket[30]. These factors include extracellular matrix proteins, laminin 5, VEGF, collagen, and PDGF[31]. The company advertises that BioXclude does not induce a foreign body response and actually possesses antibacterial properties[32]. BioXclude was introduced in 2010, but limited literature exists that provides clinical and histological results as a barrier in preforming ridge preservation.

KERATINIZED MUCOSA

Preservation of keratinized mucosa is another clinical outcome of ridge preservation. While not as important of a clinical parameter as bone volume, the presence of keratinized mucosa around implants is thought to be associated with peri-implant health and stability. While a minimum amount of keratinized mucosa around implants to promote health is not established, many authors suggest at least two

millimeters as this has been associated with decreased plaque accumulation, less inflammation, and increased patient comfort[33]. Routine plaque control and peri-implant maintenance therapy increases the longevity of dental implants[34], however; if compliance is erratic, the presence of less than two millimeters is associated with peri-implant disease[35].

The thickness of the mucosa may also affect peri-implant health due to its influence on marginal bone loss. A controlled clinical trial by Linkevicious demonstrated a statistically significant difference in the one-year marginal bone loss around implants based on the tissue biotypes. Thin biotypes averaged over a millimeter of marginal bone loss more than sites with a thick biotype[36]. The same group performed an additional study in which they augmented implant sites with thin biotypes to obtain thick biotypes. Results showed that sites augmented to thick biotypes had similar levels of crestal bone loss as those sites that were initially thick biotypes[37]. More research is needed in this area of study but preliminary studies indicate tissue biotype as an important clinical parameter for the success of dental implants.

The decision to perform ridge preservation, the choice of closure technique, and the materials utilized to complete the procedure can impact the amount of keratinized mucosa remaining in the edentulous site. The resorption of hard tissue post-extraction without ridge preservation will result in a ridge deficiency. The lack of bone volume diminishes the support the gingiva and tissue collapse is apparent[38]. Different closure techniques have demonstrated clinical success in ridge preservation. Primary wound closure[22], no primary closure[39], or an autogenous soft tissue socket seal[40] are all possible surgical variations. Flap advancement over the barrier membrane to obtain approximated

wound margins is one option in ridge preservation. This method is chiefly indicated when the barrier membrane is incompatible with exposure to the oral environment due to the propensity of the membrane to harbor bacteria. Manipulation of the soft tissue for wound closure for primary intention healing can cause a loss of keratinized mucosa in addition to other local negative consequences.[41]

Ridge preservation without wound closure for primary intention healing is possible because of materials that can be left exposed to the oral environment. As flap advancement is not necessary, the surgical procedure is simplified. In 2018, Mandarino utilized dPTFE in ridge preservation and demonstrated that on average, the keratinized tissue width was increased by four millimeters[42]. There are no similar studies with BioXclude, however, it is plausible that this membrane would also increase the keratinized tissue width due to healing by secondary intention. Thus, ridge preservation without wound healing for primary intention healing is likely to preserve the pre-extraction keratinized tissue width.

HYPOTHESIS

Keratinized tissue width will increase in all treatment groups when compared to the baseline measurements. No treatment group will prove superior in increasing keratinized tissue width.

CHAPTER 3: Methods

This single-blind, randomized clinical trial compared four different ridge perseveration techniques immediately following single tooth extraction in eighty-two patients. While this project sought the primary variables of change in ridge width and ridge height, the main objective of this thesis focuses on the secondary variable of the evaluation of keratinized tissue width. Eligible patients were randomized into four treatment groups:

Group (1) Freeze dried bone allograft (FDBA) contained with a dense polytetrafluoroethylene (Cytoplast) membrane

Group (2) FDBA contained with a Cytoplast membrane with a buccal onlay graft

Group (3) FDBA contained with a human amniotic-tissue derived membrane (BioXclude)

Group (4) FDBA contained with BioXclude with a buccal onlay graft

SUBJECT POPULATION

The target population of this study was all non-excluded patients requiring dental extraction where ridge preservation and potential dental implant therapy was indicated. The comparative design of this study obviates the need for a control group. Subjects are those patients who were referred to or present to Tingay Dental Clinic as a component of routine dental care. The patient population was composed largely of active duty service members, although some civilian, retired and medically retired patients were included.

Because the large majority of enrolled patients were active duty service members, this study limited the age of enrollment to 18-65 years old. While a somewhat arbitrary

cutoff, the infrequency with which patients outside of that range receive treatment in the clinic might skew the data set as well as potentially compromise confidentiality.

INCLUSIONS AND EXCLUSION CRITERIA

Inclusion Criteria:

1. All patients (age 18-65) referred to Tingay Dental Clinic's periodontics department for extraction and ridge preservation of a "hopeless" tooth
2. Diagnosis of "hopeless" tooth with documented confirmation of diagnosis by periodontal staff
3. Eligible for extraction and ridge preservation

Exclusion Criteria:

1. Pregnancy: Pregnant or breastfeeding women will be excluded from participation in this study
2. Age <18 or >65
3. History of allergy to involved products or any of the following: sulfa drugs, bacitracin, polymyxin B sulfate, or gentamicin
4. Current acute infection at the site (i.e. purulent discharge, appreciable abscess or cellulitis, febrile)
5. Elian Type 3
6. Sites not treatment planned for implant therapy
7. Third molar extraction sites
8. Significant systemic illness that classifies the patient as an ASA III according to the American Society of Anesthesiologists' guidelines

9. Active duty who anticipate leaving the Tingay Dental Clinic area of service within 4 months
10. Patients who are in a student status while at Fort Gordon, Georgia.

RESEARCH DESIGN

This study was a prospective, single-blinded, randomized, human clinical study. Patients with hopeless teeth requiring extraction and potential dental implant placement were considered for inclusion in this study. These patients were referred to the Periodontics Department at Tingay Dental Clinic, and this treatment was a standard component of dental care. If teeth were deemed non-salvageable by periodontics staff, the patient was asked if they would consider participating in the study. Any dentist from any specialty could designate a tooth as hopeless; however, the periodontics department staff was routinely consulted to assist in the final decision to extract the tooth. Dental prognosis is a multi-factorial process and there are no specific guidelines from the American Dental Association. Factors such as anatomy, treatment plan, current restorations, predictability, and trauma were all examples of reasons a tooth may have been deemed hopeless and therefore scheduled for extraction. Due to the high volume of teeth needing to be extracted in the US Army, any bias for extraction was mitigated. Ultimately, the treating periodontist and/or resident confirmed the decision to extract a tooth as part of the DENCOM's patient safety and "time out" verification processes. The principle investigator, staff mentor, and/or assistant investigators screened the patient for inclusion/exclusion criteria. All patients who met the criteria during the study period were asked to participate. Patients willing to participate signed consent forms after a consent process, and were given a random subject identification number for blinding

purposes. Patients had a research note placed inside the dental record to indicate active involvement in the study. Randomization for treatment groups occurred via a random number table and stratification occurred across treating practitioners. The principle investigator maintained all randomization information. The treating resident was given a sealed, opaque envelope the morning of the appointment. At this point, the treating resident no longer was blinded. The assistant investigators responsible for data collection remained blinded.

This study included all current periodontics residents in order to increase the generalizability of the results to the greater periodontics community. Board-certified staff oversaw the research as a component of the residency. A military residency had a unique advantage in that it can calibrate clinicians as part of the regular training / teaching process. This study strived to standardize as many aspects of the procedure as possible, while still allowing enough flexibility for clinicians to make decisions on behalf of the individual patient's best interest. All residents were initially calibrated and trained on nuances of the protocol, and all residents were required to have completed at least two ridge preservation procedures within the last 12 months in order to participate in the study. Staff ensured adherence to all standards.

SURGICAL PROCEDURE

The following procedure was entirely consistent with routine practice for socket preservation procedures performed in the residency program. Socket/ridge preservation is the standard of care procedure for Tingay Dental Clinic, and the research element includes only the two specific products compared in two different technique configurations. After local anesthesia application, the keratinized tissue width was

measured in millimeters from the gingival margin to the mucogingival junction at the mid-buccal location of the hopeless tooth. The tooth was then extracted in accordance with principles of minimal trauma. All multi-rooted teeth were sectioned before extraction. When appropriate, alveolar bone was removed with fine surgical diamond burs. All sockets were debrided and full thickness mucoperiosteal envelope flaps were reflected to allow access approximately ten millimeters apical on the buccal ridge and approximately five millimeters on the lingual ridge for membrane positioning. If needed, any vertical releasing incisions were at least one tooth away from the extraction site. Freeze-dried bone allograft (~250-1000 microns)(FDBA), (OraGRAFT, LifeNet Health, Virginia Beach, VA)(#MIN-CORT-.5) was placed in the socket. Patients receiving buccal onlay/augmentation received an additional one to two millimeter thick layer on the buccal surface to a depth of five to seven millimeters. One of the membranes (according to the randomization schedule) was placed over the bone graft material and adapted to extend ten millimeters apically on the buccal surface and approximately five millimeters on the lingual. If using dPTFE (Cytoplast, Osteogenics Biomedical, Lubbock, TX)(TXT1224, 12x24), membranes were trimmed to cover the socket but not encroach within one millimeters of the adjacent teeth. Amniotic tissue membrane (BioXclude, Snoasis Medical, Denver, CO)(GB-1125, 1.5 x 2) were adapted and folded as needed for site coverage, again maintaining a one millimeter distance from the adjacent teeth. Membranes were not fixed with any kind of tack or screw systems. A continuous, running Gore-Tex 5.0 suture was placed for wound stability with two interrupted sutures at mesial and distal papillae. No attempt was made to achieve primary closure, though the tissue could be advanced if applicable as a function of good suturing technique.

Clinicians deviated from the protocol if anatomical limitations warranted (i.e. aberrant nerves). Modifications were allowed for surgical details, but will not include altering selected materials or randomization. If modifications were minor (as determined by the principle investigator and other staff) the patient remained in the study.

POST-OPERATIVE MANAGEMENT

Post-operative medication was generally standardized with caveats. All patients, barring allergy or intolerance, were given amoxicillin or azithromycin, hydrocodone five milligrams, non-steroidal anti-inflammatory medications, and a chlorhexidine rinse. This regimen was consistent with routine care for the periodontics residency. Residents modified the prescriptions as needed to meet the needs of the patient (i.e. no patient was asked to endure unnecessary pain or take a drug he/she is not comfortable taking). Patients were recalled at approximately one, two, and four weeks. Sutures were removed at the two week appointment. At four weeks, the dPTFE membrane was taken out; removal of amniotic tissue membrane (BioXclude) is not required. At approximately four months, an assessment was completed including a second small volume CBCT image to evaluate the implant site and measurement of the keratinized tissue width. The implant placement is a second surgery but the research is completed at time of placement.

DATA ANALYSIS

Treating clinicians were calibrated to the study design and the measurement of keratinized tissue width during this clinical study. An ANOVA test was utilized to analyze the differences in the nominal values between the four treatment groups.

CHAPTER 4: Results

Eighty-two patients completed the clinical research project. These subjects provided one data point for one of the four treatment groups. This data signified the change in keratinized tissue width from pre-extraction to 4 four month following ridge preservation measured in millimeters with a periodontal probe. The distribution of subjects in each treatment group is listed:

Group (1) Freeze dried bone allograft (FDBA) contained with a dense polytetrafluoroethylene (Cytoplast) membrane (**18 subjects**)

Group (2) FDBA contained with a Cytoplast membrane with a buccal onlay graft **(22 subjects**)

Group (3) FDBA contained with a human amniotic-tissue (BioXclude) derived membrane (**23 subjects**)

Group (4) FDBA contained with BioXclude with a buccal onlay graft (**19 subjects**)

GROUP 1

Table 1 presents the results of patients that had ridge preservation performed with FDBA contained with a cytoplast membrane. No discrimination was made based on the position (incisor/canine/premolar/molar) of the tooth in the dental arch. While the keratinized tissue width was documented in millimeters rounded to the nearest millimeter, the data was interpreted as the percent change from the baseline to the post-extraction measurement. Based on the data, the average change in keratinized tissue width was a 22% increase from the baseline values.

Tooth Number	KTW (mm) Time of extraction	KTW (mm) 4 months of healing	Percent Change
14	2	3	+50
19	3	3	0
5	4	4	0
15	7	6	-15
20	3	4	+33
19	3	5	+66
31	1	1	0
3	3	4	+33
19	4	3	-25
20	5	6	+20
8	4	6	+50
31	2	4	100
8	6	6	0
14	9	6	-33
14	6	6	0
3	3	7	+133
3	5	5	0
19	6	5	-17

Table 1: Freeze dried bone allograft (FDBA) contained with a dense polytetrafluoroethylene (Cytoplast) membrane

GROUP 2

Table 2 presents the results of patients that had ridge preservation performed with FDBA contained with a cytoplast membrane with a buccal onlay graft. No discrimination was made based on the position (incisor/canine/premolar/molar) of the tooth in the dental arch. While the keratinized tissue width was documented in millimeters rounded to the nearest millimeter, the data was interpreted as the percent change from the baseline to the post-extraction measurement. Based on the data, the average change in keratinized tissue width was a 17% increase from the baseline values.

Tooth Number	**KTW (mm)** **Time of extraction**	**KTW (mm)** **4 months of healing**	**Percent Change**
13	5	5	0
12	3	4	+33
30	5	4	-20
14	5	4	-20
13	4	5	+25
3	5	4	-20
13	5	4	-20
19	4	2	-50
30	4	2	-50
13	5	3	-40
4	9	4	-54
19	5	6	+20

5	4	7	+75
20	3	7	+133
8	6	6	0
19	3	5	+66
19	6	12	+100
30	4	6	+50
11	4	6	+50
18	4	4	0
4	5	7	+40
4	5	8	+60

Table 2: Freeze dried bone allograft (FDBA) contained with a dense polytetrafluoroethylene (Cytoplast) membrane with a buccal onlay graft

GROUP 3

Table 3 presents the results of patients that had ridge preservation performed with FDBA contained with a human amniotic-tissue (BioXclude) derived membrane. No discrimination was made based on the position (incisor/canine/premolar/molar) of the tooth in the dental arch. While the keratinized tissue width was documented in millimeters rounded to the nearest millimeter, the data was interpreted as the percent change from the baseline to the post-extraction measurement. Based on the data, the average change in keratinized tissue width was a 14% increase from the baseline values.

Tooth Number	**KTW (mm)** **Time of extraction**	**KTW (mm)** **4 months of healing**	**Percent Change**
20	5	7	+40

19	2	2	0
19	3	3	0
14	4	3	-25
19	7	4	-43
19	3	7	+133
13	4	3	-25
14	4	3	-25
15	7	6	-15
14	3	4	+33
3	6	5	-17
19	3	4	+33
19	4	3	-25
13	4	4	0
28	3	3	0
30	2	3	+50
13	3	4	+33
19	3	5	+66
3	5	5	0
29	4	5	+25
18	3	4	+33
4	3	4	+33
14	7	6	-15

Table 3: Freeze dried bone allograft (FDBA) contained with a human amniotic-tissue (BioXclude) derived membrane

GROUP 4

Table 4 presents the results of patients that had ridge preservation performed with FDBA contained with a human amniotic-tissue (BioXclude) derived membrane with a buccal onlay graft. No discrimination was made based on the position (incisor/canine/premolar/molar) of the tooth in the dental arch. While the keratinized tissue width was documented in millimeters rounded to the nearest millimeter, the data was interpreted as the percent change from the baseline to the post-extraction measurement. Based on the data, the average change in keratinized tissue width was a 5% increase from the baseline values.

Tooth Number	**KTW (mm)** **Time of extraction**	**KTW (mm)** **4 months of healing**	**Percent Change**
18	3	4	+33
14	4	3	-25
19	3	2	-33
31	5	3	-40
19	5	4	-20
9	8	8	0
13	8	3	-43.5
30	4	5	+25
19	4	3	-25
13	4	6	+50
3	4	7	+75
14	7	6	-15

5	4	2	-50
20	3	2	-33
13	5	11	+120
5	4	6	+50
19	6	6	0
15	6	6	0
20	2	3	+50

Table 4: Freeze dried bone allograft (FDBA) contained with a human amniotic-tissue (BioXclude) derived membrane with a buccal onlay graft

All treatment groups, on average, gained keratinized tissue width after extraction and ridge preservation. As presented in the tables, this average was comprised of subjects that lost keratinized tissue width, subjects with no change, and subjects that gained keratinized tissue width. Based on the ANOVA tests, there is no statistically significant difference in the percentage change of keratinized tissue width between each treatment group. This indicates that the differences in treatment groups did not change the outcome of keratinized tissue width.

	dPTFE	Amnion Chorion
Subjects without onlay graft	18	23
Change in keratinized tissue width	+22%	+17%
Subjects with only graft	22	19
Change in keratinized tissue width	+14%	+5%

Table 5: Results summary

CHAPTER 5: Discussion

The results of this study suggest that all four ridge preservation treatment groups were equally effective in preserving the baseline buccal keratinized tissue width measured prior to the extraction of the tooth. There was not a statistically significant difference to indicate that any one ridge preservation technique was superior in preserving the amount of keratinized tissue width. This coincides with the current understanding that extraction sockets that heal by secondary intention, as opposed to primary, will lead to a preservation of keratinized tissue width.

The data sets presented in tables 1-4 display extreme outliers that bring into question the validity of the values. For example, a maxillary premolar in treatment group 4 gained six millimeters of keratinized tissue width. In the same treatment group, another maxillary premolar lost five millimeters of keratinized tissue width. It is not understood if these outliers represented a specific clinical situation that could explain the extreme values or if they were inaccurately measured.

Consequently, the technique of measuring the keratinized tissue width in this clinical research project could be responsible for these extremes. Other authors such as Mandarino utilized fabricated stents that were used as a static reference point in order to make accurate pre-extraction and post-extraction measurements[42]. In the present study, the post-extraction keratinized tissue width was measured from the mid-point of the edentulous crest to the buccal mucogingival junction. Without a static point of reference, it is difficult to accurately measure the post-extraction keratinized tissue width.

In an effort to make the results generalizable to the average clinician, many periodontal residents not only performed the surgeries but also were responsible for data

collection. While every effort was made to ensure calibration among the clinicians, the volume of clinicians involved in this project would inevitably introduce more error than if one or two clinicians were involved in the data collection portions. The interpretation of the mid-point of the edentulous ridge is difficult to objectively determine, therefore the sheer number of clinicians introduced much subjectivity.

If the majority of the subjects maintained or gained keratinized tissue width, then this information would be useful for clinicians in deciding whether or not to treatment plan soft tissue augmentation. Unfortunately, many subjects lost keratinized tissue width, which would suggest uncertainty in treatment outcomes of ridge preservation using these techniques. There is no data to explain why a loss, no change, and a gain in keratinized tissue were all witnessed in this study. Some explanations could include variations in the degree of hard tissue loss, difficult extractions, differences in gingival phenotype, and excess tension on sutures.

CHAPTER 6: Conclusion

Maintenance of the pre-extraction keratinized tissue width can be expected with ridge preservations techniques that allow healing by secondary intention. Consistent with the current literature, all four treatment groups on average either preserved or increased the keratinized tissue width in ridge preserved sites. Therefore, clinicians can apply the clinical techniques demonstrated in this study and usually assume no need for additional soft tissue augmentation at the subsequent implant sites for the purpose of widening the zone of keratinized tissue.

REFERENCES

1. Caton G, Armitage G. A new classification scheme for periodontal and peri-implant diseases and conditions – Introduction and key changes from the 1999 classification. *Journal of Periodontology*. 2018: 89(Suppl 1): S1-S8.

2. Hammerle C, Tarnow D. The etiology of hard and soft-tissue deficiencies at dental implants: A narrative review. *Journal of Periodontology*. 2018: 89 (Suppl 1): S291-303.

3. Stumbras A, Kuliesius P, Januzis G, Juodzbalys G. Alveolar ridge preservation after tooth extraction using different bone graft materials and autologous platelet concentrates: a systematic review. *J Oral Maxillofac Res*. 2019: 10: 1-14

4. Lin GH, Chan HL, Wang HL. The significance of keratinized mucosa on implant health: a systematic review. *Journal of Periodontology*. 2013: 84: 1755-1767.

5. Boynuergri D, Nemli SK, Kasko YA. Significance of keratinized mucosa around dental implants: a prospective comparative study. *Clin Oral Implants Res.* 2013: 24: 928-933.

6. Buser D, Sennerby L, De Bruyn H. Modern implant dentistry based on osseointegration: 50 years of progress, current trends and open questions. Periodontology 2000 2017: 73: 7-21.

7. Stumbras A, Kuliesius P, Januzis G, Juodzbalys G. Alveolar ridge preservation after tooth extraction using different bone graft materials and autologous platelet concentrates: a systematic review. J Oral Maxillofac Res. 2019: 10: 1-14.

8. Amler M. The time sequence of tissue regeneration in human extraction wounds. Oral Surgery, Oral Medicine and Oral Pathology. 1969: 27: 309-318.

9. Carlsso H, Thilander H, Hedegard B. Changes in the upper alveolar process after extractions with or without insertion of an immediate full denture. Acta Odontol Scand. 1967: 25: 21-43.

10. Araujo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experiemental study in the dog. Journal of Clinical Periodontology. 2005: 32: 212-218.

11. Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. Int J Periodontics Restorative Dent. 2003: 23: 313-323.

12. Tan WL, Wong TL, Wong MC, Lang NP. A systematic review of post-extractional alveolar hard and soft tissue dimensional changes in humans. Clin Oral Implants Res. 2012: 23: 1-21.

13. Pietrokovski J, Massler M. Alveolar ridge resorption following tooth extraction. J Prosthet Dent. 1967: 17: 21-27.

14. Araujo M, Silva C, Misawa M, Sukekava F. Alveolar socket healing: what can we learn? Periodontology 2000 2015: 68: 122-134.

15. Oghli A, Steveling H. Ridge preservation following tooth extraction: a comparison between atraumatic extraction and socket seal surgery. Quintessence International. 2010: 41: 605-609.

16. Poulias E, Greenwell H, Hill M. Ridge preservation comparing socket allograft alone to socket allograft plus overlay xenograft: a clinical and histologic study in humans. Journal of Periodontology. 2013: 84: 1567-1575.

17. Darby I, Chen S, Buser D. Ridge preservation techniques for implant therapy. Int J Oral Maxillofac Implants. 2009: 24: 260-271.

18. Sbordone C, Toti P, Martuscelli R, Guidetti F, Porzio M, Sbordone L. Retrospective volume analysis of bone remodeling after tooth extraction with and without deproteinized bovine bone mineral insertion. Clin Oral Implants Res. 2016: 27: 1152-1159.

19. Buser D, Ingimarsson S, Dula K. Long-term stability of osseointegrated implants in augmented bone: A 5-Year prospective study in partially edentulous patients. The International Journal of Periodontics & Restorative Dentistry. 2002; 22: 108-117.

20. Iasella JM, et al. Ridge preservation with freeze-dried bone allograft and a collagen membrane compared to extraction alone for implant site development: a clinical and histologic study in humans. Journal of Periodontology 2003; 74.7: 990-999.

21. Barone A, et al. Xenograft Versus Extraction alone for ridge preservation after tooth removal: a clinical and histomorphometric study. Journal of Periodontology 2008; 79.8: 1370-1377.

22. Froum S, et al. Histological comparison of healing extraction sockets implanted with bioactive glass or demineralized freeze-dried bone allograft: a pilot study. Journal of Periodontology 2002; 73.1: 94-102.

23. Carranza F, Newman M, Takei T. Carranza's Clinical Periodontology. Philadelphia: W.B. Saunders Company, 2002.

24. Lekovic V, Camargo PM, Klokkevold P. Preservation of alveolar bone in extraction sockets using bioabsorbable membranes. Journal of Peridontology. 1998: 69: 1044-1049.

25 Carbonell JM, Sanz M, Santos A, Puzol A. High-density polytetrafluoroethylene membranes in guided bone and tissue regeneration procedures: a literature review. International Journal Oral Maxillofac Surg. 2007: 65: 748-752.

26. Bartee BK. The use of high-density polytetrafluroethylene membrane to treat osseous defects: clinical reports. Implant Dent. 1995 4: 21 – 26.

27. Hoffman O, Bartee B, Beaumont C. Alveolar bone preservation in extraction sockets using non-resorbable dPTFE membranes: a retrospective non-randomized study. Journal of Periodontology. 2008: 79.8: 1355-1369.

28. Arbab H. Ridge preservation comparing a nonresorbable PTFE membrane to a resorbable collagen membrane: a clinical and histologic study in humans. Implant Dentitry. 2016: 25.1: 128-134.

29. Fotek P, Neiva R, Wang HL. Comparison of dermal matrix and polytetrafluoroethylene membrane for socket bone augmentation: a clinical and histologic study. Journal of Periodontology. 2009: 80.5: 776-785.

30. Koob TJ. Angiogenic properties of dehydrated human amnion/chorion allografts: therapeutic potential for soft tissue repair and regeneration. Vascular Cell. 2014: 6.1: 10.

31. Niknejad H. Properties of the amniotic membrane for potential use in tissue engineering. Eur Cells Mater. 2008: 15: 88-99.

32. Rosen P. A retrospective consecutive case series using mineralized allograft combined with recombinant human platelet-derived growth factor BB to treat moderate to severe osseous lesions. International Journal of Periodontics and Restorative Dentistry. 2011: 31.4: 335.

33. Araujo M, Lindhe J. Peri-implant health. Journal of Periodontology. 2017: 89: 249-256.

34. Monje A, Wang HL, Nart J. Association of preventive maintenance therapy compliance and peri-implant diseases: a cross-sectional study. Journal of Periodontology. 2017: 88: 1030-1041.

35. Monje A, Blasi G. Significance of keratinized mucosa/gingiva on peri-implant and adjacent periodontal conditions in erratic maintenance compliers. Journal of Periodontology. 2019: 90: 445-453.

36. Linkevicius T, Apse P, Grybauskas S, Puisys A. The influence of soft tissue thickness on crestal bone changes around implants: a 1-year prospective controlled clinical trial. Int J Oral Maxillofac Implants. 2009: 24: 712-719.

37. Linkevicius T, Puisys A, Linkeviciene L, Peciuliene V, Schlee M. Crestal bone stability around implants and horizontally matching connection after soft tissue thickening: a prospective clinical trial. Clin Implant Dent Relat Res. 2015: 17: 497-508.

38. Locante WM. The nonfunctional immediate provisional in immediate extraction sites: a technique to maximize esthetics. Implant Dent. 2001: 10: 254-258.

39. Kim DM, De Angelis N, Camelo M. Ridge preservation with and without primary wound closure: a case series. Int J Periodontics Restorative Dent. 2013: 33: 71-78.

40. Tal H. Autogenous masticatory mucosal grafts in extraction socket seal procedures: a comparison between sockets grafted with demineralized freeze-dried bone and deproteinized bovine bone mineral. Clin Oral Implants Res. 1999: 10: 289-296.

41. Landsberg CJ. Socket seal surgery combined with immediate implant placement: A novel approach for single-tooth replacement. Int J Periodontics Restorative Dent. 1997: 17: 140-149.

42. Mandarino D. Alveolar ridge preservation using a non-resorbable membrane: randomized clinical trial with biomolecular analysis. Int J. Oral Maxillofac. Surg. 2018: 47: 1465 – 1473.