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The Effect of Biologic Materials and Oral Steroids on Radiographic and Clinical Outcomes of Horizontal Alveolar Ridge Augmentation.

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The Effect of Biologic Materials and Oral Steroids on Radiographic and Clinical Outcomes of Horizontal Alveolar Ridge Augmentation.

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

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Abstract

The purpose of this study was to investigate if the addition of biologic materials and/or oral steroids would affect horizontal bone gain, or the bone density of the grafted bone in horizontal alveolar ridge augmentations. A retrospective chart review was completed to assess the clinical and radiographic outcomes of 53 ridge augmentation patients. An average bone gain of 3.6mm of width was found in our study based on radiographic analysis. There were no statistically significant differences found in the linear bone gain with the addition of biologic materials and steroids. A marginally statistically significant difference was found in the bone density when biologics were added (p-value=0.0653). No statistically significant difference found in the bone density with the addition of oral steroids. The use of tenting screws and resorbable occlusive membranes and a combination of allograft and xenograft bone materials provides significant clinical and radiographic dimensional changes in alveolar ridge width.

THE EFFECT OF BIOLOGIC MATERIALS AND ORAL STEROIDS ON RADIOGRAPHIC AND CLINICAL OUTCOMES OF HORIZONTAL ALVEOLAR RIDGE AUGMENTATION.

By: AMY REICHERT, DDS

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DEPARTMENT OF PERIODONTICS

Purpose: The purpose of this study was to investigate if the addition of biologic materials and/or oral steroids would affect horizontal bone gain, or the bone density of the grafted bone in horizontal ridge augmentations.

Methods: A retrospective chart review was completed to assess the clinical and radiographic outcomes of 53 horizontal ridge augmentation patients. Information was gathered regarding surgical technique, grafting materials, post-operative healing, bone growth and bone density

changes as quantified on a CBCT scan. Statistical analysis was completed to learn whether the addition of biologic materials or oral steroids would enhance the post-operative outcomes.

Results: An average bone gain of 3.6mm of horizontal augmentation was found in our study based on radiographic analysis. There were no statistically significant differences found in terms of linear bone gain with the addition of biologic materials and steroids. A marginally statistically significant difference was found in the addition of biologics in terms of the density of the grafted bone (p-value=0.0653). There was no statistically significant difference found with the effect of oral steroids and bone density.

Conclusion: The use of tenting screws and resorbable occlusive membranes and a combination of allograft and xenograft materials provides significant clinical and radiographic dimensional changes in alveolar ridge width. Within the limitations of this retrospective study, we found that the addition of biologic materials to the bone graft did not make a significant difference in the amount of bone gain for future implant placement. Lastly, the addition of oral steroids to the post-operative prescription list does not provide a statistically significant difference in final outcomes.

Introduction

Dental implants have become a preferred replacement for missing teeth. Frequently, the remaining alveolar bone does not maintain adequate bone volume for future implant placement. A common procedure to correct deficient future implant sites prior to placement of implants is augmentation of the alveolar ridge. Following tooth extraction, there is immediate resorption of the alveolar ridge, both in a vertical and horizontal dimension, in the majority of the population.[1] If this resorption becomes severe enough, there will not be adequate space for the placement of an optimal diameter dental implant. According to one study, the average loss of width post extraction is 3.87 mm, while the average loss in height is 1.67 mm.[2] In order to recreate this space, augmentation of the alveolar ridge with bone graft material and space maintaining membranes is needed.[3,4]

Regeneration techniques of the alveolar bone have been used since the 1980s in order to regenerate and repair defects and other abnormalities. The addition of biologic agents to enhance the outcomes of these procedures has been developed more recently; GEM 21, for example, was introduced as recently as 2012. With these biologic agents being relatively new additions in terms of their usage in dental medicine, it stands to reason that at this time there is currently not enough evidence to support the claims made by the manufacturers in the outcomes of ridge augmentation and ultimately in successful implant placement.[5,6]

Various techniques have been developed for alveolar ridge augmentation based on employment of different reinforcement devices to support particulate bone graft material.[7,8,9,10] Rigid support of grafted material utilizing tenting screws or reinforced membranes is used to support the volume of the graft.[11,12] Additionally, screws and tacks are used for fixation of membranes.[11,13] Over the years, various methods for this type of procedure have been presented.

In this study we investigated various open ridge augmentation techniques. Open augmentation techniques provide greater access to the area to be grafted, allow for easier instrumentation, manipulation and stabilization of the membrane, and increased ability to properly release gingival flaps to obtain tension free closure. Tenting screws allow for significant space maintenance, graft support and can help to define the area where augmentation is needed for future implant placement.[14,15] Since space maintenance is one of the most important factors that allows for horizontal augmentation of the alveolar ridge, tenting screws are crucial for creating and maintaining that space.[16,17,18] Bone grafts allow for additional space maintenance and provide a scaffold for angiogenesis and osteogenesis to take place.[11]

Bone graft materials that are typically used for horizontal ridge augmentations include both allograft and xenograft materials. Freeze dried bone allograft is human derived bone graft material and the xenograft bone substitute used in this study is bovine derived. These types of grafting materials have osteogenic bone properties meaning that is provides an environment where osteogenesis can readily occur. They have both demonstrated new bone growth histologically.[19,20] There use in bone regeneration has been extensively studied and these materials have proven that their use can provide great results in both vertical and horizontal ridge augmentation, ridge preservation, and intrabony defect regeneration.[21,22] Resorbable non-crosslinked collagen membranes are used to help contain and stabilize the bone graft material

while they also keep epithelial cells from invading the graft material. They can maintain their cell exclusive function for 4-8 weeks but can remain present for up to 6 months as they slowly degrade.[23,24] These membranes are biocompatible and promote soft tissue healing with angiogenesis.[25] The combination of these materials allow for the basic principles of bone regeneration to be met.

Biologic materials can potentially provide an additional benefit by enhancing the regeneration process. Biologic materials are the newest phenomena to be explored in periodontal research with the aim to create materials that could select for the types of cells needed for faster and more efficient regeneration of the alveolar bone.[26,27] Biologic materials most commonly used in periodontics include Emdogain (EMD), recombinant human platelet-derived growth factor-ββ (GEM 21), and platelet rich plasma (PRP) from autologous blood concentrate.[5]

Emdogain is enamel matrix derivative, a substance that includes mostly Amelogenins. It was first introduced for periodontal therapy in 1996 and is derived from porcine developing tooth buds. It has been credited with the recruitment of fibroblasts, osteoblasts, periodontal ligament cells, cementoblasts, and mesenchymal stem cells.[28,29] Emdogain is delivered with Propylene Glycol Alginate (PGA) which allows for adhesion of the material to the tooth. Emdogain is well studied in the area of periodontal regeneration of intrabony defects.[30] It has shown statistically significant improvements in probing depth reduction, attachment gain, and bone fill.[31]

GEM 21 is a synthetic bioactive protein, recombinant human platelet derived growth factor – rhPDGF-BB that has been highly purified in a laboratory. It was first approved for periodontal use in 2012 and has been credited with promoting increased chemotaxis, mitogenesis, and angiogenesis.[32] These mechanisms enhance the functioning of osteoblasts, cementoblasts, and fibroblasts, which are the cells responsible for periodontal regeneration.[5,32,33]

It has been shown that GEM 21 contains 1,000 times more active growth factor than either platelet rich plasma (PRP) or platelet rich fibrin (PRF).[34]

PRP is derived from the patient's own whole blood that is centrifuged to remove red blood cells and platelet-poor plasma. PRP was first used in 1987 during open heart surgery and is now used in orthopedics, dentistry, neurology and many other fields. It contains at least 60 growth factors that are thought to enhance soft tissue healing, bone augmentation, and periodontal regeneration by selecting for ideal cell populations, specifically PDGF-AB, PDGF-BB, Transforming Growth Factor-β (TGF-B), Vascular Endothelial Growth Factor (VEG-F), Connective Tissue Growth Factor (CTGF), Insulin-like Growth Factor (IGF), and Endothelial Growth Factor (EGF).[35,36,37,38] The research in both animal and human models is presently still limited when considering its effect on bone augmentation. Most can agree that Emdogain can enhance regeneration in periodontal defects,[28] GEM 21 can enhance bone density,[39] and PRP can enhance soft tissue healing during the immediate post-operative time period.[40] However, evidence is still inconclusive when evaluating the enhancement of bone formation in large guided bone regeneration procedures.[5,33,41] Most studies seem to show that PRP does not provide any additional benefit when compared to bone graft alone when assessing the amount of bone gain following its use.[40,42]

Corticosteroids are often used post operatively to control inflammation. The glucocorticoid group is used for this type of pharmacotherapy. Methylprednisolone is often the steroid of choice for dental procedures, which is a synthetic analog to the natural steroids that are produced in the adrenal cortex. Unbound glucocorticoids like methylprednisolone have the ability to cross cell membranes and bind receptors that effect transcription and protein synthesis. This gives them the ability to interfere with inflammatory mediators to decrease the

inflammatory response. By this same mechanism, however, they also suppress the humoral immune response, which can effect wound healing.[43] The majority of studies looking at post-operative steroid use in dentistry are aimed at third molar extractions and found promising results for reduction inflammation.[44,45] Studies that have looked at corticosteroid use in periodontics, however, are extremely limited and more specific research is needed in this area.

Three dimensional x-rays have quickly become a standard diagnostic tool for the treatment of dental implant patients. Cone beam commuted tomography (CBCT) was first introduced in the U.S. in 2001 and is a more localized version of the standard medical computed tomography (CT) scan, and therefore takes the image of the patient using significantly less radiation. CBCT X-rays are divergent and form a cone instead of a fan beam as in the original medical grade CT scanner. CBCT viewing software allows for linear horizontal and vertical measurements to be made, as well as limited bone density readings based on the grayscale. The Hounsfield units (HU) were created as a quantitative scale for radiodensity measurement in standard CT images, but could not be accurately transferred to the CBCT scans initially. More recently, however, studies have found that with the improvement of CBCT technology the ability to convert grey levels into specific HU can be easily done.[46] Linear and vertical measurements can be made easily with the measurement tools included in the CBCT viewing software.[47] Three-dimensional evaluation both pre-operatively and post-operatively gives the surgeon the ability to locate anatomical structures, plan the surgery, and evaluate dimensional changes achieved due to bone grafting.[48]

Currently, in clinical practice there is a lack of standardization and evidence based clinical guidelines for the use of biologic agents and post-operative steroids in horizontal ridge augmentation. While all the products claim to have beneficial properties, there is a lack of

consistent evidence-based data that supports their enhancement of clinical outcomes and gives realistic values to the extent of suggested gains. Typically, practitioners use biologic agents and materials based on their own clinical experience. This study aims to analyze if that paradigm holds true with the expected outcome that the addition of biologic agents and prescription of post-operative oral steroids in horizontal ridge augmentation will give similar results as to the technique itself without adding costly biologics when assessing for gains in horizontal ridge augmentation width and final implant placement as desired outcome variable.

The aim of this retrospective study was to evaluate the results of horizontal alveolar ridge augmentation utilizing the tent screw technique with resorbable barriers and as it pertains to ridge dimensional changes, bone density of the grafted bone, and successful placement of implants in grafted areas. Furthermore, the aim was to also analyze if the use of biologic materials and post-operative steroids had any additional benefit on the final outcome of ridge augmentation procedures. This project will attempt to gather more information and to analyze it to determine any possible influence that post-operative oral steroids may have on the outcomes of ridge augmentation and subsequent implant placement.

Methods

Study Design

A retrospective chart review of patients who underwent horizontal ridge augmentation in Department of Graduate Periodontics between April 2013 to December 2017 was completed. Institutional Review Board approved the study (IRB approval #HM20004398_CR1).

Exclusion criteria included patients with simultaneous horizontal ridge augmentation and implant placement, those with grafting materials other than particulate bone graft, those with non-resorbable membranes, those without tenting screws, and those who did not have both a preoperative and postoperative cone-beam computed tomography (CBCT) scan. Patients were not excluded based on their medical history findings. One hundred and eighty-eight total ridge augmentation patients were narrowed to fifty-three patients based on the above exclusion criteria. All patients underwent a preoperative CBCT scan, followed by a postoperative scan between 1-24 months postoperatively before implant placement. The average length of time from surgery to post-operative scan was seven months. Scans were taken with a CareStream 8100 3D Kodak machine and depending on the field of view each scan was associated with a dosage of 30-80 µSv of radiation to the patient. Dimensional changes and bone density of the grafted sites were assessed with CareStream CBCT scan

software. Horizontal measurements were made 3 mm apical to the alveolar crest in the area of future implant placement to account for any potential discrepancies, and reference points on adjacent dentition served as landmarks. Bone density of the grafted bone was assessed on the postoperative scans using the CareStream cursor tool. The specific area of grafted bone was evaluated at 3 different sites within 3 mm of each other and the values were averaged to create a single value for each patient. These values were evaluated statistically to analyze bone augmentation outcomes with the tent screw technique as well as compare these findings between patients who received biologics and those who did not. Additionally, these values were compared between patients who received steroid medications postoperatively and those who did not.

Surgical Technique

All procedures were performed under local anesthesia with or without intravenous sedation by residents at Virginia Commonwealth University School of Dentistry. The ridge augmentation procedures were performed via a crestal incision over edentulous ridge extending over the surgical area with full thickness mucoperiosteal flaps on the buccal and lingual aspects. All sites received various mixtures of mineralized freeze-dried bone allograft (FDBA, Salvin Dental Specialties, Charlotte, NC), particulate bovine-derived hydroxyapatite xenograft (Bio-Oss, Geistlich Pharma North America, Princeton, NJ; Endobond, Zimmer Biomet, Warsaw, IN) and allograft putty materials (Exactech Optecure +CCC, Salvin Dental Specialties, Charlotte, NC; Dynablast, Keystone Dental, Burlington, MA), Tent screws (Salvin Dental Specialties, Charlotte, NC) of a length of 6mm (3mm within the bone and 3mm for aid in augmentation) were secured at the recipient site. The number of patients who received each combination of graft material are as follows,

FDBA/Bio-Oss (29), FDBA (6), Exactech Optecure/Bio-Oss (5), Exactech Optecure/FDBA (4), 70/30 Mix/Bio-Oss (5), Dynablast/Bio-Oss (3) FDBA/Endobond (1). The mixed bone was then packed in the area of augmentation via a bone condenser.

One of a variety of resorbable collagen membranes (Bio-Gide, Geistlich Pharma North America, Princeton, NJ; Dynamatrix, Keystone Dental, Burlington, MA; Optimatrix, Osteohealth, Shirley, NY), acellular dermal matrix (Alloderm GBR, Biohorizons, Birmingham, AL), or a bovine collagen sponge with synthetic particulate graft (Zimmer Biomet, Warsaw, IN) were placed over the bone graft and the membranes were secured with tacks (Meisinger, Neuss, Germany), sutures (Chromic gut, Ethicon, Somerville, NJ), or tucked beneath the periosteum. Twenty-two of the fifty-three patients were treated with adjunctive biologic materials, including Emdogain (Straumann, Basel, Switzerland) GEM 21 (Osteohealth, Shirley, NY), and PRP (Harvest TerumoBCT, Lakewood, CO) while thirty-one received bone graft alone.

All patients received a preoperative dose of 2 g Amoxicillin or 600 mg Clindamycin prior to treatment, as well as 500 mg Amoxicillin TID or 300 mg Clindamycin TID for 1 week. Additionally, patients were given the option to take pain medication (800 mg Ibuprofen q8h, 5/325 mg Hydrocodone APAP q8h, or Tylenol 3 30 mg q8h) to manage postoperative discomfort. Additionally, based on the severity of the procedure, some patients were prescribed steroids (Medrol Dose Pak 4 mg) to manage postoperative swelling. Patients were advised to use 0.12% Chlorhexidine mouth rinse twice daily for plaque control and its antimicrobial effect for 2 weeks following the surgery.

Depending on postoperative presentation patients were seen at 1 week, 2 weeks, 1 month, and 6 months postoperatively. If any flap dehiscence occurred, the surgical site and

graft were examined for any signs of infection. If infection was present, the site was irrigated, and the patient received an additional week of antibiotic therapy. Additional antibiotic courses were also prescribed when healing was delayed.

Study Groups

Twenty-two of the fifty-three patients were treated with adjunctive biologic materials, including Emdogain (Straumann, Basel, Switzerland), GEM 21 (Osteohealth, Shirley, NY), and PRP (Harvest TerumoBCT, Lakewood, CO) while thirty-one received bone graft alone. Biologic materials were often used in cases where significant augmentation was needed in areas with severe defects. Additionally, thirty-five of the fifty-three patients were given post-operative oral steroids, while eighteen did not. Sixteen patients received both biologics and oral steroids.

Statistical Methods

Two independent raters measured a subset of the cases to test for accuracy of measurements. The ICC of the two raters was high, at 0.94. One rater then completed the rest of the measurements which were used for analysis.

Patient demographics were summarized using descriptive statistics. Paired t-test was used to test for difference in bone level before and after the graft. Effect of biologics and steroids on bone growth and graft density were tested using ANOVA. All models adjusted for the time from bone graft placement to the time the CBCT that was used to measure bone level and density was taken. Overall models for post-operative bone level adjusted for age, gender, jaw (maxilla, mandible) and location (posterior, anterior). Backwards elimination was used to find a

parsimonious model, however variables of interest (biologics, steroids, time since surgery) were maintained in all models.

Results

A total of 53 patients were included in the analysis. Patient demographics are given in Table 1. Most patients were female (n=40, 75%), while thirteen patients were male (n=13, 25%), with an age range of all patients being 31-79 years old and an average age of 60.9 (SD=11.6). Almost all of the cases included have seen implants successfully placed (92%), but there was one failure and 3 cases are still in progress. The cases that are still in progress are still waiting due to scheduling issues at the dental school.

Patients saw an average bone gain of 3.6mm (SD=1.82), which was statistically significant (P-value<0.0001; 95% CI: 3.06-4.07). Almost half of the patients received biologics (n=22, 42%) and a little over half received steroids (n=35, 66%). Patients who received biologics were similar to those who did not in terms of age (p-value=0.0912), gender (p-value=0.3446), baseline bone level (p-value=0.2130), and time between the follow-up time for the post-operative scan (p-value=0.1158). However, after categorizing patients into two groups (<50 and $\geq$ 50), there was a significant difference in rate of biologics used based on age (p-value=0.0544). Patients in the younger age group were more likely to get biologics than those in the older age group (75% vs 36%), although the sample size in the young age group was small (n=8). For steroids, there was also no significant differences in terms of age (p-value=0.3740), gender (p-value=0.7796), or time between the follow-up time for the post-operative scan (p-value=0.5708).

But there was a difference in baseline bone level favoring those who got steroids (5.67 vs 4.89, p-value=0.0453).

Bone Level

Initial models for post-operative bone level included only the baseline bone level, the healing time (as defined by time between the date of surgery and the post-operative CBCT), and either the use of biologics or use of steroids. The use of biologics was not associated with a significant difference in bone level after bone graft (P-value=0.6048). The use of steroids was also not associated with a significant increase in bone level after graft (p-value=0.8589).

The final model based on biologics included baseline bone level (p-value=0.0209), bone level at 1-24 months after surgery (p-value=0.0998), and location in the mouth (posterior, anterior) (p-value=0.0135). Use of biologics was again not statistically significantly related to increased post-operative bone level (p-value=0.5234). Higher baseline bone level was associated with an increase in post-operative bone level. For each 1mm of increase in baseline bone level, there was an associated post-operative gain of 0.46mm. Posterior sites had higher post-operative bone level width than anterior sites (9.36mm vs 7.54mm).

The final model based on post-operative steroid is included baseline bone level (p-value=0.0469), 1-24 months following surgery (p-value=0.0685), and location in the mouth (posterior, anterior) (p-value=0.0131). The use of post-operative oral steroids was, again, not statistically significantly related to increased post-operative bone level (p-value=0.6338). Higher baseline bone level was associated with an increase in post-operative bone level. For each 1mm of increase in baseline bone level, there was an associated post-operative gain of 0.42 mm. Posterior sites had higher post-operative bone level than anterior sites (9.26 vs 7.57).

Bone Graft Density

Initial models for post-operative bone density included only the healing time (as defined by time between the date of surgery and the post-operative CBCT), and either use of biologics or use of steroids. The use of biologics was not associated with a significant difference in bone density after bone graft (P-value=0.1493). The use of steroids was also not associated with a significant increase in bone density after graft (p-value=0.3566).

In the adjusted model for graft density based on biologics, there was a marginally significant difference in bone graft density based on the use of biologics (p-value=0.0653). The estimated bone graft density for patients who received biologics was 1113.63 compared to 836.5 for those who did not (average difference: 277, 95% CI: -18.3, 572.5). The adjusted model also included time between surgery and post-operative CBCT (p-value=0.1457) and patient gender (p-value=0.0808). Females had a marginally significantly higher post-operative density than males (1135.04 vs 815.1, 95% CI on difference: -40.7, 680.6). Results are given in Table 6.

In the adjusted model for graft density based on steroids, none of the covariates of interest were significantly associated with density and therefore the adjusted model reduced to the initial model.

Since some patients received both steroids and biologics, analysis was also repeated to determine if modeling both steroids and biologics simultaneously had any impact on the results. There were no substantial changes in the models when modeling simultaneously and results are presented in Tables 7 and 8. For bone level, neither steroids (p-value=0.6962) nor biologics (p-value=0.3318) were associated with change in bone level, but baseline bone level (p-value=0.0214) and location in the mouth (p-value=0.0125) did. For bone density, there was

marginal evidence that biologics increased bone density (p-value=0.0543), along with months from surgery (p-value=0.1686) and gender (p-value=0.0905), but no association with steroids (p-value=0.3053).

Tables and Figures

Table 1: Sample Demographics and Baseline Measures

		n	%
Gender			
	Male	13	25%
	Female	40	75%
Biologics		22	42%
Steroids		35	66%
Implant Placed			
	Yes	49	92%
	No	1	2%
	In Progress	3	6%
		Mean	**SD**
Age		60.89 years	11.63
Baseline Bone Level		5.42 mm	1.33
Follow-up Bone Level		8.92 mm	2.03
Average Growth		3.56 mm	1.82
Follow-up Density		1033.04	514.17
Time between Graft and Post-Op CBCT		7.32 months	4.15

Table 2: Unadjusted Association between Bone Level and Use of Biologics and Steroids

	Post-Operative Bone Level		
	Mean*	SE	P-value
Biologics			
Yes	8.83 mm	0.39	
No	9.10 mm	0.33	
Difference	-0.27 mm	0.52	0.6048
Steroids			
Yes	8.95 mm	0.31	
No	9.05 mm	0.44	
Difference	-0.10 mm	0.55	0.8589

*Mean adjusted for time since bone graft only

Table 3: Unadjusted Association between Bone Graft Density and Use of Biologics and Steroids

		Bone Graft Density		
		Mean*	SE	P-value
Biologics				
	Yes	1157.8	110.5	
	No	944.50	92.8	
	Difference	213.3	145.6	0.1493
Steroids				
	Yes	985.3	87.80	
	No	1125.8	122.5	
	Difference	-140.40	150.9	0.3566

*Mean adjusted for time since bone graft only

Table 4: Adjusted Model for Association between Bone Level and Biologics

	Estimated Mean Bone Level	SE	p-value
Baseline Bone Level (1mm Increase)	0.46 mm	0.19	0.0209
Biologics (Y/N)			0.5234
Yes	8.63 mm	0.38	
No	8.28 mm	0.45	
Months from Surgery (1-month increase)	-0.10 mm	0.06	0.0998
Location			0.0135
Anterior	7.54 mm	0.60	
Posterior	9.36 mm	0.28	

Table 5: Adjusted Model for Association between Bone Level and Steroids

	Estimated Mean Bone Level	SE	p-value
Baseline Bone Level (1mm Increase)	0.42 mm	0.21	0.0469
Steroids (Y/N)			0.6338
Yes	8.55 mm	0.33	
No	8.29 mm	0.51	
Months from Surgery (1-month increase)	-0.11 mm	0.06	0.0685
Location			0.0131
Anterior	7.57 mm	0.61	
Posterior	9.26 mm	0.27	

Table 6: Adjusted Model for Association between Bone Graft Density and Use of Biologics

	Estimated Bone Density	SE	p-value
Biologics (Y/N)			0.0653
Yes	1113.63	110.96	
No	836.52	109.16	
Months from Surgery (1-month increase)	28.00	19.94	0.1457
Gender			0.0808
Male	815.10	149.74	
Female	1135.04	84.30	

Table 7: Adjusted Model for Association between Bone Level and Use of Biologics and Steroids

	Estimated Mean Bone Level	SE	p-value
Baseline Bone Level (1mm Increase)	0.50 mm	0.21	0.0214
Biologics (Y/N)			0.3318
Yes	8.66 mm	0.41	
No	8.12 mm	0.47	
Steroids (Y/N)			0.6962
Yes	8.50 mm	0.34	
No	8.29 mm	0.53	
Location			0.0125
Anterior	7.43 mm	0.66	
Posterior	9.36 mm	0.30	

Table 8: Adjusted Model for Association between Bone Density and Use of Biologics and Steroids

	Estimated Bone Density	SE	p-value
Biologics (Y/N)			0.0543
Yes	1148.56	115.89	
No	857.67	110.97	
Steroids (Y/N)			0.3053
Yes	927.04	94.08	
No	1079.18	129.60	
Months from Surgery (1 month increase)	26.53	18.98	0.1686
Gender			0.0905
Male	847.99	152.96	
Female	1158.23	87.16	

Figure 1: Scatterplot of Density by Age and Use of Biologics (shows distribution of age in sample and higher rate of biologics in younger group).

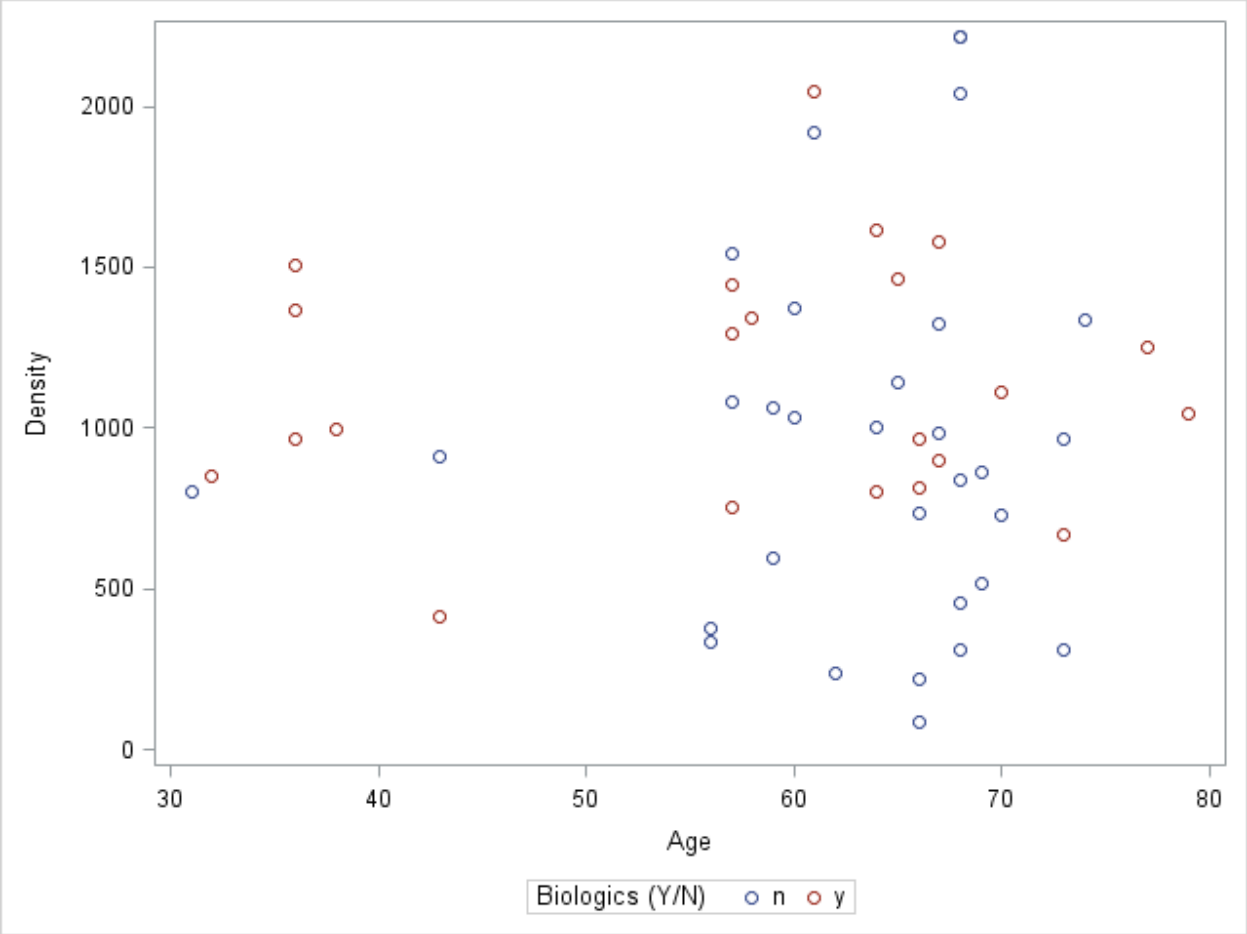


Figure 2: Preoperative CBCT scan of the left maxilla demonstrating a narrow ridge requiring augmentation prior to implant placement. a) linear measurement from distal surface of terminal tooth to area of future implant placement, b) measurement to 3mm below the alveolar crest, c) linear measurement of horizontal width.

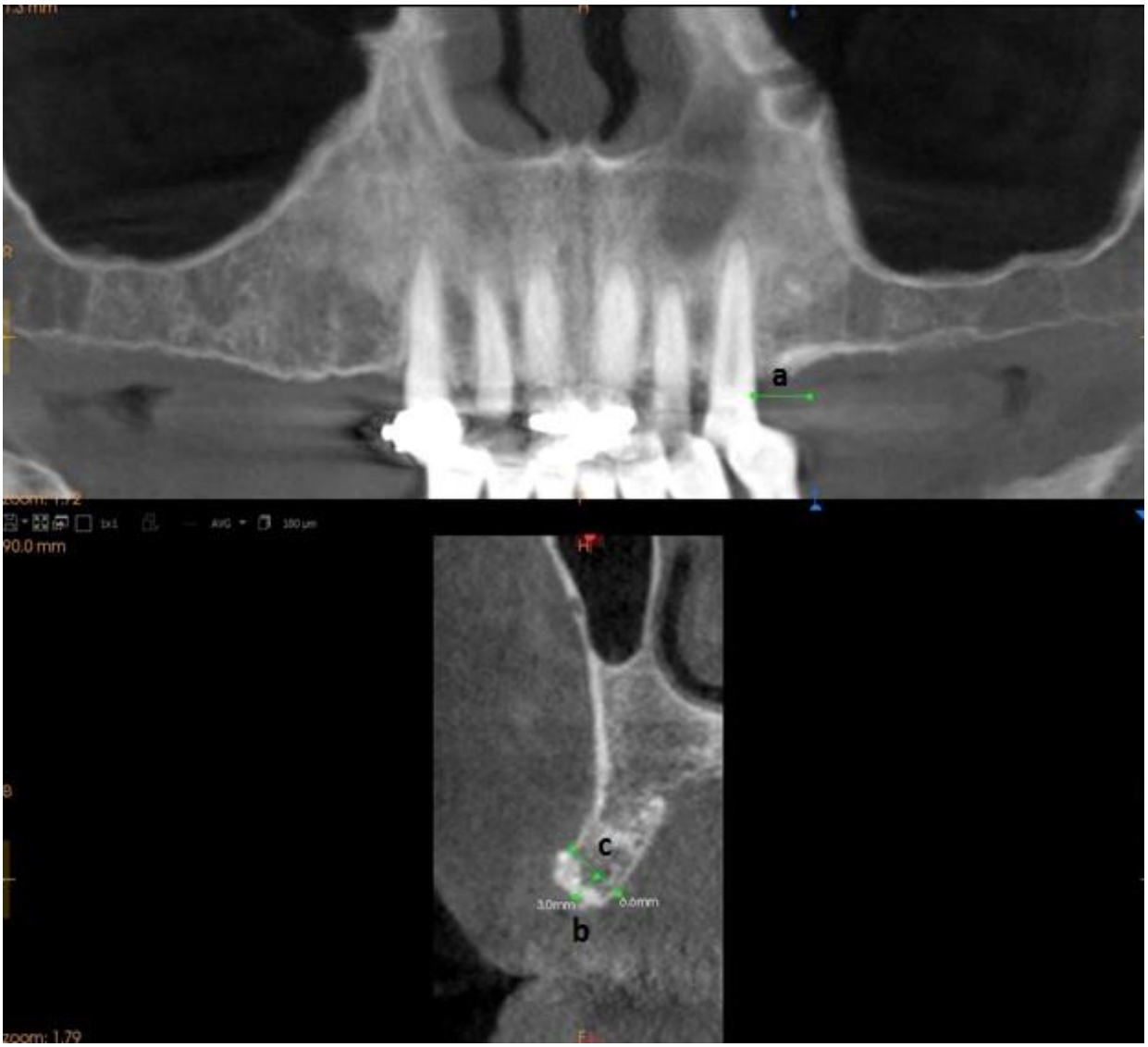
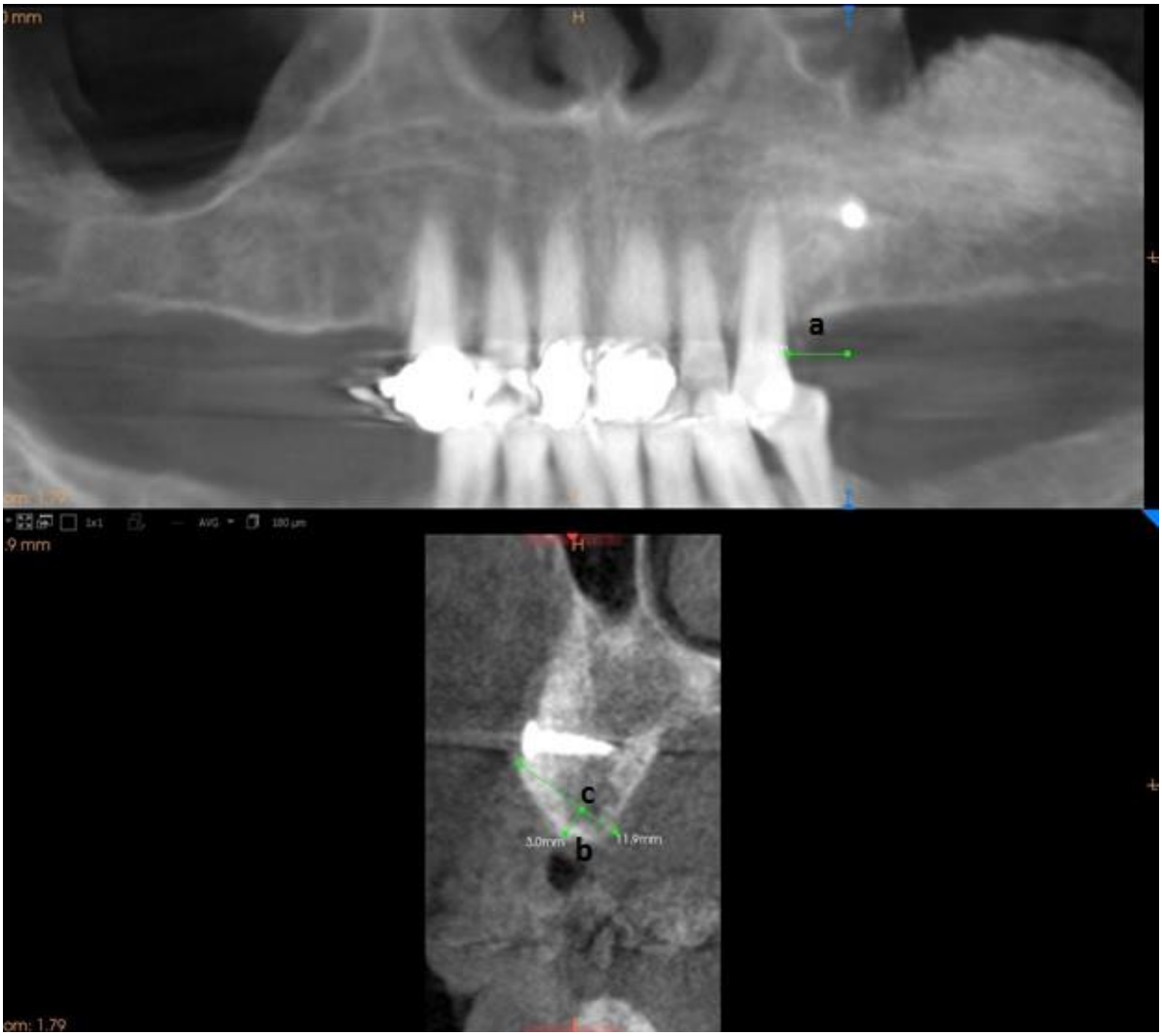


Figure 3: Postoperative CBCT scan taken 7 months following surgery demonstrating linear measurement in the same area as Figure 2. a) linear measurement from distal surface of terminal tooth to area of future implant placement (same measurement as the pre-operative scan), b) measurement to 3mm below the alveolar crest, c) linear measurement of horizontal width.



Discussion

The aim of this study was to evaluate the success of the tent screw horizontal bone augmentation technique as far as dimensional and density changes with or without the use of adjunct biologics materials or post-operative steroids. Often there is not a definitive rationale behind the use of biologics from patient to patient. Providers are many times likely to include the use of biologics for cases of greater severity when it may be more difficult to obtain significant augmentation. Based on the statistical analysis, our cases showed an average bone gain of 3.6mm of horizontal augmentation, which is consistent with data from other studies showing similar results, between 3.09-3.33 mm of horizontal bone gain with the tent pole technique.[14] Studies utilizing resorbable membranes without tenting screws reported horizontal gains of 1.65 mm.[49]

The use of biologics and steroids were not associated with significant improvements in the amount of horizontal bone gain obtained. A marginally statistically significant difference was seen in the level of bone density with the use of biologics compared to those who did not receive biologics in the adjusted model for bone graft density changes. GEM 21 has specifically been associated with increases in bone mineral density and bone hardness in animal models.[50] GEM 21 has also shown significant improvement in clinical attachment level and bone fill in the treatment of periodontal defects, however the evidence analyzing its effect on horizontal alveolar bone augmentation is extremely limited.[39] PRP, on the other hand, has only consistently shown

improvement in soft tissue healing, and has not demonstrated improvements in bone regeneration.[40,51] When selecting for each biologic material alone, there were no significant differences among the three types of biologics included in the study. The number of patients in each group was also not significant enough to draw any conclusions. Oral steroid use was not associated with a significant change in bone density.

If the use of biologic materials does not provide an obvious improvement in the dimensional changes of the grafted bone, it may cause us to question their necessity especially when considering the added expense to both the doctor and the patient. Their use marginally improves the bone density, but the wide confidence interval implies that there was a great amount of variability in the density measurements compared with the small sample size. More controlled studies assessing each of these materials and comparing their effects would be needed to confirm this potential finding. The statistical analysis shows lack of precision in the study design and a small sample size. Because of this, significant conclusions cannot be drawn from the results of the bone mineral density. This slight difference in bone mineral density may or may not be mostly associated with GEM 21 versus the other biologic materials. These results beg to question the necessity of these products, especially considering the cost they add to the procedure. Depending on the type of material being utilized, the manufacturers' prices can range from $100-$750. To justify adding these material costs to ridge augmentation procedures, evidence to support the use of these products should be convincing and consistent with procedure application. Further studies should examine the differences between specific biologic materials and their ability to improve outcomes of guided bone regeneration procedures.

Oral steroid use is considered following dental surgical procedures to ensure that post-operative inflammation can be controlled. Many literature reviews have been completed to assess

the effects of corticosteroid use on the healing process following dental surgery. These studies have generally found that there is a significant decrease in post-operative edema and pain with the use of oral steroids.[37,45] One study found that there was a marginally increased risk for infection with the use of oral steroids, but this was just a relative risk of 1.0041. It was also found that there is a potential for adrenal suppression with the extended use of oral steroids.[52] There were no reports of decreased healing, but it is difficult to quantify this type of parameter. Many of these side effects are associated with long term use and are rarely seen with the administration of steroids for less than 5 days.[53] Although there was no significant change in the patients who received post-operative oral steroid therapy in terms of clinical and radiographic outcomes in our study, there is still something to be said for the reduction of an excessive inflammatory response. Depending on each individual patient's medical history, the addition of oral steroids can still be a useful tool for large surgical procedures. For smaller procedures, the use of other medications, like NSAIDs could be considered instead.

As a retrospective study, this study has several limitations. First and foremost, there were a variety of different resorbable membrane brands, allogenic and xenogenic bone grafting materials, and biologic materials used between different patients. Variations in surgical materials presents a limitation because although the materials used in these procedures are very similar, there are still slight differences that could potential affect the surgical outcomes. Timelines differed for each patient based on their scheduling preferences rather and this introduced variability, especially for the radiographic bone measurements. Linear measurements of the augmented bone were performed rather than volumetric analysis due to available software. Although linear measurements can provide a great deal of information considering bone gain following ridge augmentation procedures, but these measurements only provide a two-

dimensional measurement. There is software available that can superimpose three-dimensional images to provide volumetric measures to compare pre-operative and post-operative images. Three-dimensional analyses can provide additional information as far as the newly formed anatomy of the alveolar ridge. Additionally, similar software is available to more accurately evaluate bone mineral density. Unfortunately, these types of software were not available to us, but they could have given us even more accurate and comprehensive measurements for our data. The patient population presented a wide age range along with variations in medical histories. Such a wide range of ages in our patient population causes a discrepancy because these patients have such varying medical histories and physiologic healing patterns. These differences could potentially skew the data to better outcomes with the younger patients.

It is very difficult to account for so many variables with this type of study, so a prospective study with a similar method of measuring changes in the bone would be indicated for future research.

Conclusion

In conclusion, the use of tenting screws and resorbable occlusive membranes and a combination of allograft and xenograft materials provides significant clinical and radiographic dimensional changes in alveolar ridge width. The average bone gain that can be expected with this technique is 3.6mm of horizontal augmentation. Additionally, for every 1mm of bone width that is present at baseline, about 0.42-0.46mm of bone gain can be expected following grafting. Within the limitations of this retrospective study, we found that the addition of biologic materials to the grafting materials did not make a significant difference in the amount of bone gain for future implant placement. Additionally, the addition of oral steroids to the post-operative prescription list does not provide a statistically significant difference in final outcomes. Overall, the tent screw surgical technique combined with particulate bone graft and resorbable collagen membranes allows for significant horizontal bone augmentation for future implant placement.

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