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HUMAN RANDOMIZED CONTROLLED TRIAL

Ridge preservation following tooth extraction using bovine xenograft compared with porcine xenograft: A randomized controlled clinical trial

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Abstract

Background: The primary purpose of this study was to histologically determine if there is a significant difference in new bone formation, residual graft material, and connective tissue/other when ridge preservation is accomplished using a bovine versus a porcine xenograft.

Methods: Forty-four patients needing a single rooted tooth extraction and ridge preservation in preparation for dental implant placement were recruited in the study. After minimally traumatic tooth extraction, alveolar ridge dimensions were measured using a custom-fabricated acrylic stent. Patients were then randomized 1:1 to receive ridge preservation using either bovine or porcine xenograft material. A trimmed dense polytetrafluoroethylene (d-PTFE) membrane was overlaid on the graft material, the mucoperiosteal flaps were replaced, and the surgical site was sutured. After 18 to 20 weeks of wound healing, sites were surgically re-entered, ridge dimensions were again measured using the previously fabricated acrylic stents and a bone core sample of the grafted site was harvested for histomorphometric analysis.

Results: Thirty eight of the 44 enrolled patients completed the study, 17 from the bovine group and 21 from the porcine group. Histologically, there were no statistically significant differences between the groups for mean percentage of vital bone formation (bovine = 36.21%, porcine = 31.27%, $P = 0.49$), residual graft material (bovine = 20.47%, porcine = 19.52%, $P = 0.82$) and connective tissue/other (bovine = 43.32%, porcine = 49.21%, $P = 0.19$). For secondary outcomes, there were no significant differences between the groups for mean change in buccal ridge height, lingual ridge height, and ridge width. However, a higher number of patients in the porcine group had additional grafting at the time of implant placement, either because of thin buccal plate or failure of implant stability.

Conclusion: The findings suggest that ridge preservation with porcine xenograft results in comparable histomorphometric outcomes and dimensional stability with bovine xenograft.

KEYWORDS

alveolar bone grafting, alveolar bone loss, bone resorption, bone transplantation, dental implants, tooth extraction

1 | INTRODUCTION

The effectiveness of alveolar ridge preservation has repeatedly been confirmed by various studies including a systematic review by Avila-Ortiz et al.[1] who compared the outcomes of tooth extraction with and without ridge preservation in nonmolar teeth. They found that ridge preserved sites had a mean of 1.89 mm less loss in the buccolingual ridge dimension and 2.07 mm less loss in the vertical ridge dimension. Autogenous bone has often been considered the gold standard in bone grafting[2] as it does not induce immunologic reactions and contains osteogenic, osteoinductive and osteoconductive properties.[3] However, harvesting autogenous bone often involves a separate surgical site which increases patient morbidity and adds to clinical treatment time.[4] These factors have driven the dental market to produce substitutes for autogenous grafts leading to the continued development of allografts, alloplasts, and xenografts.

One of the most commonly used xenografts in dentistry is deproteinated bovine bone matrix (DBBM).[4] This bovine-derived xenograft undergoes a multistage purification process to remove all organic components, leaving an anorganic crystalline hydroxyapatite bone mineral matrix that is biocompatible as well as both physically and chemically similar to human bone. The bone architecture after processing results in an interconnecting macro and microporous arrangement that facilitates angiogenesis and the formation and ingrowth of new bone. DBBM has been used successfully in various periodontal and oral surgical procedures including ridge preservation,[5] guided bone regeneration,[6] sinus augmentation,[7] and buccal contour augmentation,[8] among others.

However, despite the effectiveness of bovine xenograft in oral surgical procedures, alternative sources of xenograft material have been sought due either to concerns over potential bovine spongiform encephalopathy (BSE) transmission[9] or possible patient objections for religious reasons.[10] BSE is a progressive neurologic disorder of cattle that results from ingesting meat-and-bone meal containing misfolded protein known as a prion. Prions are resistant to sterilization procedures and result in damage to the central nervous system of the cattle.[9] The spread to humans, which presents as a variant of Creutzfeldt-Jakob disease (vCJD), is caused by eating contaminated beef.[11] BSE has not been linked to use of bovine-derived xenografts in oral surgical procedures, but the limited ability to screen for prions may be of concern to some.[9] In addition, the use of certain animal products may present a religious conflict for people of some faiths.[10]

Similar to bovine xenografts, the crystalline structure of porcine xenografts is comparable to human bone after processing.[12] The anorganic bone mineral matrix has interconnecting macro and microscopic porous architecture which reduces the bulk density of the graft and allows for more void space for new bone growth. Even though porcine-derived products are widely available in the dentistry, there are limited data reporting on the osteoconductive effectiveness of these products and how they compare to the commonly used bovine xenografts.

The authors have published numerous studies examining wound healing after ridge preservations with a variety of materials and techniques.[13–20] However, to the authors' knowledge, there are no published data directly comparing wound healing outcomes when performing ridge preservation with bovine xenografts versus porcine xenograft materials. Thus, the primary objective of this study is to determine histologically if there is a significant difference between ridge preservation using bovine and porcine xenografts by comparing the percentage of vital bone, residual graft and connective tissue and other (CT/other) tissues. The null hypothesis is that there is no significant difference in the mean percentage of vital bone observed histologically between patients that received porcine-derived xenograft versus bovine-derived xenograft for ridge preservation in extraction site between 18 and 20 weeks after grafting. Secondarily, the clinical dimensional stability of the alveolar ridge after ridge preservation with bovine and porcine xenografts was analyzed.

2 | MATERIALS AND METHODS

2.1 | Participant enrollment

This parallel two-arm randomized prospective clinical trial was approved by the Institutional Review Board of UT Health San Antonio (UTHSA) in agreement with the Helsinki Declaration of 1975, revised in 2013. Studies by the authors' research group have shown standard deviations for percentage of vital bone formation ranging from 11.9 to 22.4.[13–19] A Mann-Whitney U test at 5% level of significance ($\alpha = 0.05$) and an 88.5% power determined that 14 histologic samples from each group would be necessary to discern a mean difference in percentages of new bone formation of one standard deviation.

To compensate for an anticipated 30% dropout rate, 22 patients were recruited for each arm of the study. Patients were recruited from the UTHSA School of Dentistry Graduate Periodontics Clinic between August 2016 and November 2017. The following inclusion criteria were applied: (1) a single rooted tooth requiring extraction and replacement with a dental implant, (2) tooth root in an ideal position for future implant placement allowing a bone core sample to be harvested within the former socket, (3) adequate restorative space for implant supported restoration, and (4) $\geq$10 mm of alveolar bone height without impingement on adjacent vital structures. Patient exclusion criteria included (1) individuals who

could not commit to the specific follow-up time period, (2) pregnancy or intended to become pregnant during the study period, (3) smoked > 10 cigarettes/day, (4) had active infection other than periodontal disease, or (5) had systemic illnesses or medications that may hinder wound healing.

2.2 | Surgical protocol

All patients were treated by 12 calibrated surgeons after patients gave written informed consent before enrollment into the study. Surgeons included periodontal residents covered by board-certified periodontal faculty. The current study is one of 13 similar studies done by this research group over the past decade. All residents learn the methodology of the study protocol during the beginning of their training by teaching from a single faculty member (B.L.M.). A stone model was made for each patient from alginate impressions. A 1-mm thick clear thermoplastic acrylic stent* of the surgical site and adjacent teeth were made from the stone model to allow for repeated clinical measurements of the alveolar ridge throughout the study period. After local anesthesia, a minimal full-thickness flap was reflected to a point approximately 3 mm apical to the alveolar crest, and minimally traumatic tooth extraction was performed. Soft tissue debridement of the socket was followed by copious irrigation using sterile saline, and the alveolus was inspected for dehiscence or fenestration to ensure inclusion criteria were still met. Randomization was then performed by opening an unlabeled envelope from an initial stack of 44 envelopes, 22 envelopes for bovine (active control group) and 22 for porcine (experimental group). Clinical measurements were then made using a periodontal probe† along with the acrylic stents. The depth of the socket was measured to the nearest 0.5 mm from the base of the socket to the buccal and lingual alveolar crest. A blunt-ended gauge‡ was used to measure the buccal plate thickness 1 mm apical to the buccal alveolar crest to the nearest 0.1 mm. Four reference holes were drilled into the stents, marking the locations from which repeated measurements would be made. Two holes were made on the occlusal aspect of the stent for measurement of the buccal and palatal-lingual ridge height to the nearest 0.5 mm and two holes were made on the buccal and palatal-lingual flanges, 4 mm apical to the alveolar crest location for measurement of the ridge width using ridge calipers§ to the nearest 0.5 mm. If, after tooth extraction, there was a dehiscence present at the extraction site that extended more than 50% of the depth of the socket, the patient was exited from the study.

After collecting all clinical measurements, ridge preservation was performed using either cancellous bovine¶ or cancellous porcine# xenograft. The graft material was condensed into the socket incrementally for complete apico-coronal fill. The bone graft extended to the height of the interproximal bone, resulting in slight overfilling only at the buccal and lingual bony crests. In the presence of a fenestration in the buccal plate, a collagen socket repair membrane‖ was placed on the internal aspect of the alveolus before ridge preservation. A trimmed dense polytetrafluoroethylene (d-PTFE) membrane** was then placed over the grafted site extending approximately 3 mm apical to the buccal and palatal-lingual crest but taking care not to contact adjacent teeth. As primary closure was not attempted, the reflected flaps were replaced at their original position and sutured using 4-0 PTFE sutures.††

Patients received post-operative instructions and were prescribed an antibiotic regimen consisting of 500 mg amoxicillin orally every 8 hours for 7 days. If patients were allergic to penicillin, they were prescribed 100 mg doxycycline every 12 hours for 7 days. Participants were also instructed to rinse with 15 mL of 0.12% chlorhexidine gluconate mouth rinse twice a day for 30 seconds for a total of 2 weeks. Post-operative pain was managed with non-steroidal anti-inflammatory drugs and narcotic analgesics as needed. Participants were seen for post-operative visits at 7 to 10 days for suture removal and at 1 month for membrane removal.

Cone bean computer tomography or intraoral radiographs were made for precise implant placement planning. Patients returned for the second surgical appointment after 18 to 20 weeks of wound healing. After patients were anesthetized, full-thickness flaps were reflected and the customized acrylic stent was used for repeatable measurements of the buccal and palatal-lingual ridge height and width. If a depression in the coronal aspect of the ridge was present, indicating some residual socket, measurement of the depression depth was recorded. A trephine drill with a 2 mm internal and 3 mm external diameter‡‡ was used to obtain a bone core sample of 8 mm in length from the previously ridge preserved site. The bone core sample was also part of the initial implant osteotomy. The sample was stored in a 10% neutral buffered formalin solution. The operator's determination of tactile bone density was recorded as a type 1, 2, 3, or 4 as per Lekholm and Zarb.[21] The osteotomy was then completed using the appropriate implant drills per manufacturer's protocol followed by implant placement. The operator also decided

* Clear Splint Biocryl 1 mm/125 mm Round, Great Lakes Orthodontic Labs, Tonawanda, NY.

† UNC-15 probe; G. Hartzell & Son, Concord, CA.

‡ Iwanson gauge, Salvin Dental Specialties, Charlotte, NC.

§ Castroviejo ridge calipers, Salvin Dental Specialties, Charlotte, NC.

¶ Bio-Oss, Geistlich Pharma NA, Wolhusen Switzerland.

Zcore Porcine Xenograft, Osteogenics Inc., Lubbock, TX.

‖ Zimmer socket repair membrane, Zimmer Biomet Dental, Oakland, NJ.

** Cytoplast TXT-200 Singles, Osteogenics Biomedical, Lubbock, TX.

†† Cytoplast PTFE suture, Osteogenics Biomedical, Lubbock, TX.

‡‡ Trephine bur, Salvin Dental Specialties, Charlotte, NC.

if additional bone grafting was required for indications such as implant thread exposure or thin bony plate on the buccal or lingual aspect of the implant. If implant stability was not achieved, sites were re-grafted for future implant placement. Patients returned for post-operative visits 10 to 14 days after the surgical appointment and were followed until they were ready for implant restorations.

2.3 | Histologic processing and analysis

Histologic processing steps and morphometric analysis for this study are the same used with previously established guidelines from this research group.[14–20] The bone core samples were removed from the trephine burs and stored in 10% neutral buffered formalin for at least 72 hours before processing. Processing was initiated using hydrochloric acid (HCl) solution* to decalcify the harvested bone core samples for no more than 2 hours. The specimens were then placed in a tissue processor,† which gradually dehydrated the samples using sequential 1-hour ethanol baths of 75%, 90%, and 100% along with a xylene bath and two paraffin baths. A paraffin embedder‡ was used to embed the samples in paraffin wax, and samples were sectioned to a thickness of 4 μm and placed on glass slides. Each bone core sample provided seven to nine slices that were stained with Harris Hematoxylin and counter stained with acid fuchsin and a combination of orange G and eosin Y.§ The best quality slice nearest to the center of the bone core was selected from the sample for histomorphometric analysis. If any artifact was present in the innermost slice, the next closest slice was selected.

For histomorphometric analysis, the single examiner was blinded to whether bone core sample slices being analyzed were of the control or experimental group. Each slice was initially examined at 4× magnification¶ and to create a working image for identification of tissue types, a series of overlapping JPEG images were made and imported to image processing software.# The "photomerge" command was then applied to combine all the overlapping images into one continuous image for each bone core. This improved the working image quality and aided in the accuracy of differentiating and outlining the three different tissue types using a mouse cursor—vital bone, residual graft, and connective tissue or other‖ (Figures 1 and 2). Tissue types were analyzed between 20× and 40× to ensure accurate identification and traced on the working images on the image processing software. Vital bone tissue was identified as presence of osteocytes in mineralized tissue, residual graft was identified as absence of osteocytes in mineralized tissue, and the remaining tissues were considered connective tissue or other. Tracings of the three separate tissue types were saved as JPEG images and converted to binary (black and white) images using image analysis software.** The binary images were used to calculate the total number of pixels in each image. The percentage of vital bone formation, residual graft, and connective tissue or other was determined by calculating the total number of pixels in each tissue component divided by the total number of pixels in all 3 tissue components.

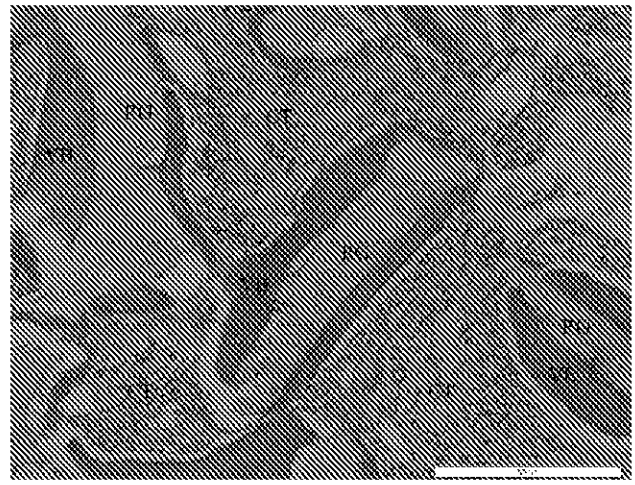

FIGURE 1 Representative sample of tissue types from a porcine xenograft site (10×): VB = vital bone, RG = residual graft, CT = connective tissue/other. (Harris hematoxylin and a proprietary combination eosin counterstain)

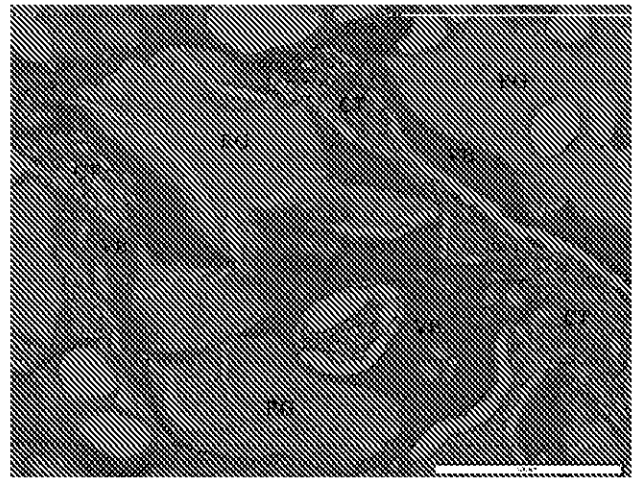

FIGURE 2 Representative sample of tissue types from a bovine xenograft site (10×): VB = vital bone, RG = residual graft, CT = connective tissue/other. (Harris hematoxylin and a proprietary combination eosin counterstain)

* Surgipath Decalcifier II, Leica Biosystems Inc., Buffalo Grove, IL.

† Tissue-Tek VIP 1000, Sakura Finetek USA Inc., Torrance, CA.

‡ Leica RM2155 automated microtome, Leica Microsystems Inc, Buffalo Grove, IL.

§ Treosin, Statlab Medical Products, Lewisville, TX.

¶ Vano AH-2, Olympus America, Center Valley, PA.

Adobe Photoshop CC, Adobe, San Jose, CA.

‖ CellSens Version 1.4 Software, Waltham, MA.

** Image J, National Institutes of Health, Bethesda, MD.

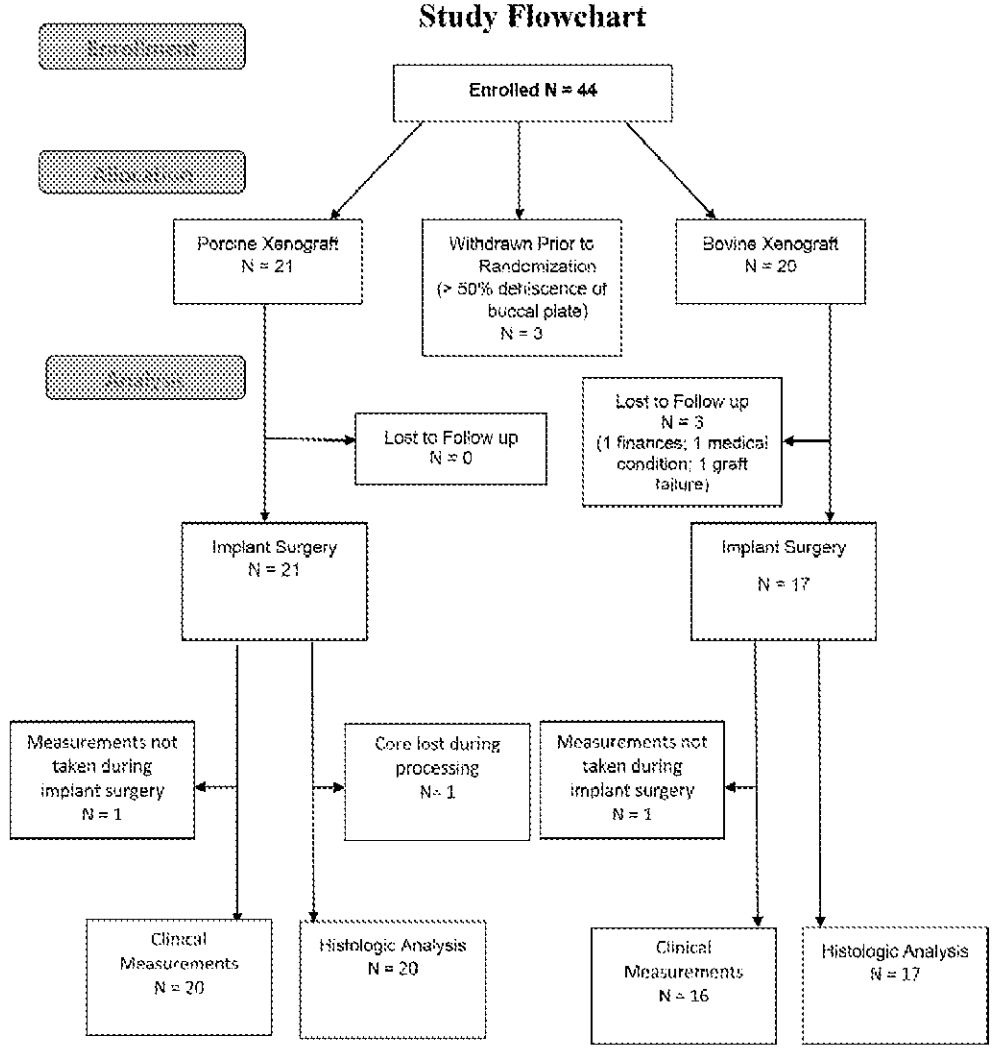

FIGURE 3 Study flowchart

2.4 | Statistical analyses

R statistical computing language[22] and statistical software* were used for the statistical analysis of this study. The histologic analysis of tissue types in each bone core sample and clinical dimensional analysis of the alveolar ridge allowed for computations of the sample size, mean, standard deviation, median, and range for both the bovine and porcine xenograft groups. Two-sample *t*-tests were performed to determine significant differences between the two groups. Interaction terms were used to determine the differences in the relationship between two variables for each group and r-square was used to determine if additional variables increased the model fit. All statistical analysis was performed with a cutoff of alpha < 5% as significant and was two-sided. Relationships between clinical and histologic parameters were assessed using Pearson correlations.

* SAS Version 9.4 for Windows, SAS Institute, Cary, NC.

3 | RESULTS

Forty-four patients were enrolled in the study, 27 females and 17 males, with an average age of 57 years (range 24 to 83 years) (Figure 3). Six patients were withdrawn leaving 38 patients who completed the study. Three patients were withdrawn before randomization because of having a dehiscence at the extraction site that was > 50% of the depth of the socket. The other three patients withdrawn were lost during the follow-up period and were all from the bovine group. One was withdrawn because of lack of finances, one was withdrawn because of the diagnosis of a medical condition, and one was withdrawn because of complete encapsulation of graft material at the time of implant placement. Patients withdrawn were excluded from statistical analysis. Of the 38 patients who completed the study, the average age was 57 years (range 24 to 82 years) and consisted of 25 females and 13 males. None of the patients were current smokers, nine patients were previous smokers, and four patients had type 2 diabetes mellitus but were well controlled with the most recent HbA1c < 7%.

TABLE 1 Primary histologic outcomes

Variables		Bovine	Porcine	95% CI	*P*
Vital bone %	Mean (SD)	36.21 (26.51)	31.27 (16.23)	(−9.49, 19.37)	0.49
Residual graft material %	Mean (SD)	20.47 (15.29)	19.52 (9.19)	(−7.33, 9.23)	0.82
%CT/other	Mean (SD)	43.32 (15.78)	49.21 (10.79)	(−14.8, 3.02)	0.19

TABLE 2 Ridge dimensional changes

Variables		Bovine (N = 16)	Porcine (N = 20)	95% CI	*P*
Baseline ridge width (mm)	Mean (SD)	9.03 (0.83)	10.5 (1.86)	(−2.49, −0.45)	0.01
Initial buccal plate thickness (mm)	Mean (SD)	0.74 (0.36)	1.1 (0.58)	(−0.69, −0.01)	0.04
Change in lingual ridge height (mm)	Mean (SD)	1.56 (1.75)	1.60 (1.74)	(−1.23, 1.15)	0.95
Change in ridge width (mm)	Mean (SD)	−0.38 (1.23)	−1.03 (1.3)	(−0.22, 1.53)	0.14
Change in ridge width (%)	Mean (SD)	−4 (14)	−10 (13)	(4, 15)	0.23

None of the patients had post-operative infections or other complications following surgery. When d-PTFE membranes were removed, the underlying soft tissue was pink-to-red in color and appeared as healing granulation tissue. By the time of implant placement, all sites appeared with normal keratinized mucosa. Thirty-eight bone core samples were obtained, 21 from the porcine group and 17 from the bovine group (Figure 3). One bone core sample from the porcine group was lost to processing. One customized acrylic stent was lost from each treatment group, thus clinical measurements were made for 16 patients in the bovine group and 20 patients in the porcine group. In the porcine group, the ridge width measurements were made incorrectly for one patient; thus, in this group 20 patients had vertical measurements analyzed and 19 had horizontal measurements analyzed. All patients in the bovine group achieved primary implant stability, whereas lack of implant primary stability was experienced in two patients in the porcine group. Ten patients received additional bone grafting at the time of implant placement: three from the bovine group and five from the porcine group because of thin buccal plate or some implant thread exposure, plus the two patients in the porcine group whose implants were not stable. Those sites were re-grafted with the intention of implant placement in the future.

The mean baseline ridge width for the bovine group was 9.03 mm (SD = 0.83), whereas the porcine group was 10.50 mm (SD = 1.86). This was a statistically significant difference between the groups ($P = 0.01$). The mean buccal plate thickness of the bovine group and porcine group were 0.74 mm (SD = 0.36) and 1.10 mm (SD = 0.58), respectively. The difference between groups was statistically significant ($P = 0.04$). The bovine and porcine groups had a mean healing time of 134.75 days (SD = 5.25) and 133.70 days (SD = 6.32), respectively, with no significant difference between groups ($P = 0.60$). At surgical re-entry, three sites of the bovine group and seven sites of the porcine group required additional grafting ($P = 0.46$).

The histomorphometric analysis for primary outcomes is summarized in Table 1. No statistically significant differences between the bovine and porcine groups were found for mean percentage of vital bone formation, residual graft material or connective tissue or other. Dimensional changes of the alveolar ridge are presented in Table 2. There was a mean increase in buccal ridge height in both the bovine and porcine groups of approximately 1.5 mm, with no statistically significant difference between the groups ($P = 0.62$). There was also a mean increase in lingual ridge height for both the bovine and porcine groups of approximately 1.5 mm, with no significant difference between groups ($P = 0.95$). Both groups had a small mean loss of ridge width, again with no significant difference between groups.

No significant correlations were found between the percentage of vital bone formation and changes in ridge width for the bovine group ($r = 0.23$, $P = 0.39$) or porcine group ($r = 0.01$, $P = 0.96$). Likewise, no significant correlations were found in either group for vital bone formation and change in buccal ridge height (bovine: $r = 0.28$, $P = 0.29$; porcine: $r = 0.16$, $P = 0.51$) or change in lingual ridge height (bovine: $r = -0.23$, $P = 0.4$; porcine: $r = 0.33$, $P = 0.16$). In addition, box plots revealed no significant group-interaction effect for correlations between percentage of vital bone formation and presence or absence of a dehiscence ($P = 0.99$); sites in maxillary versus mandibular arches ($P = 0.94$); sites in the anterior versus posterior arch position ($P = 0.19$), or clinical bone density type ($P = 0.79$). There was also no significant association between treatment (bovine, porcine) and need for additional grafting at time of implant placement ($P = 0.46$). The correlation between percentage of vital bone formation and smoking status could not be determined as there were no current smokers enrolled in the study.

A post-hoc power analysis was also performed. With regard to percent vital bone, a primary endpoint, the current study bovine mean of 36.2% vital bone with the standard deviation estimated as the average of the standard deviations in each

group 21.37 (bovine = 26.51, porcine = 16.23) (Table 1), and assuming a common SD, $n = 17$ subjects per treatment group, and two-sided T-testing with $\alpha = 0.05$, this study will attain power of 80% for testing H_0: $\mu_B = \mu_P$, where μ_B and μ_P are the means of percent vital bone with bovine and porcine xenografts, respectively, if μ_P exceeds μ_B by one SD.*

4 | DISCUSSION

The goal of this study was to compare the histologic and clinical outcomes of ridge preservation using bovine and porcine xenografts. Analysis of primary outcomes revealed no significant histological differences in mean vital bone formation between ridge preservation with cancellous bovine xenograft and cancellous porcine xenograft after 18 to 20 weeks of healing. For the porcine group, vital bone formation of 31.3% in the current study was similar to previously reported results for ridge preservation using cortical and collagenated cortico-cancellous porcine xenograft showing vital bone formation of 36.8% and 41.4%, respectively, after 3 months of healing.[23] Conversely, the ridge preservation study of Guarnieri et al.[24] showed a greater percentage of new bone formation (57.4%) at 4 months of healing than the current study. Both studies used cancellous porcine xenografts that were processed from the same tissue processor, and ridge preserved sites were allowed approximately the same amount of healing time. The difference between the two studies is that Guarnieri et al.[25] included premolar- molar sites and used a resorbable collagen membrane over the graft material, whereas the current study used a d-PTFE membrane and only included anterior and premolar sites.

A study of ridge dimensional changes reported a decrease in alveolar ridge volume of 30.2% when ridge preserving with cortical porcine xenograft and 28.8% when ridge preserving with collagenated cortico-cancellous porcine xenograft.[25] Conversely, the current study showed an average loss of ridge width of 4% and 10% in bovine and porcine groups, respectively. In terms of alveolar ridge dimensions, the bovine group had a mean loss of ridge width of 0.38 mm, and the porcine group had a mean loss of 1.03 mm. Although this was not significantly different between groups, all ridge width measurements were made 4 mm apical to the alveolar crest, and thus changes observed only reflect changes of the coronal portion of the alveolar ridge. Further, although change in ridge width was not significantly different between groups, the average loss of 0.65 mm more ridge width in the porcine group is consistent with the greater number of patients who received additional grafting at the time of implant placement because of thin buccal bone over the implant in the porcine group versus the bovine group. Although several sites in both treatment groups were found to have low tactile bone density at the time of implant placement, all 17 implants in the bovine group attained sufficient stability, but two of 21 implants in the porcine group failed to attain stability. Given that the average vital bone formation in the former socket region was not significantly lower in the porcine group, it is possible that lack of stability at these sites may have been related to lower bone density in the native bone apical to the socket into which the implant was placed.

Theoretically, a potential advantage of using porcine xenograft is the absence of BSE transmission endemically by pigs, unlike bovine xenografts. However, BSE transmission to pigs is possible parenterally (intracranially, intravenously and intraperitoneally), but pigs exposed to cattle brain material during feeding did not contract the disease.[26] A possible explanation as to why oral exposures are less effective than parenteral exposures is the cattle-pig species barrier.[26] This barrier includes various mechanisms that prevent spread of a virus or disease from one species to another.

Microscopically, bovine and porcine xenografts appear very similar to each other as well as to human bone. Both xenografts are highly porous and allow for the formation and ingrowth of new bone. However, in the current study the gross characteristics of the porcine xenograft material appeared finer and more delicate compared to bovine bone of similar particle size. On multiple occasions, it was observed that somewhat more porcine graft material by volume was required to completely fill extraction sockets compared to bovine bone graft material. It is possible that the "flaky" texture of the porcine material allowed denser packing under gentle pressure during ridge augmentation.

5 | CONCLUSION

To the authors' knowledge, this is the first study to directly compare both histologically and morphometrically the outcomes of ridge preservation using bovine and porcine cancellous bone xenografts. The current findings indicate that there are no significant differences in vital bone formation, residual graft particles, and connective tissue and other between the groups after 18 to 20 weeks of wound healing. There were no significant differences in the clinical dimensional changes of the alveolar ridge between the groups. However, a higher number of patients in the porcine group had additional grafting at the time of implant placement, either because of thin buccal plate or failure of implant stability.

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*PASS Version 15, NCSS, Kaysville, UT.

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