Alveolar Ridge Expansion by Osseodensification-Mediated Plastic Deformation and Compaction Autografting: A Multicenter Retrospective Study

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Introduction: *Osseodensification preserves bone bulk, facilitates compaction autografting, and deforms trabecular bone in an outward strain, which result in alveolar ridge plastic expansion. The aim of this retrospective study was to evaluate ridge expansion after osseodensification.*

Materials and Methods: *Patients treated with implant placement through osseodensification were evaluated. The alveolar ridge width was measured at the level of the crest and 10 mm apical to the crest before and after osseodensification. Insertion torque and implant stability quotient (ISQ) values were recorded at implant placements. Expansion values were grouped into the following 3 groups according to the initial alveolar ridge width: group 1: 3 to 4 mm ($n = 9$), group 2: 5 to 6 mm ($n = 12$), and group 3: 7 to 8 mm ($n = 7$).*

Results: *Twenty-one patients who received 28 implants were included. Twenty-six implants were integrated, resulting in a survival rate of 92.8%. There was a significant difference in the mean expansion value at the coronal aspect of the ridge between group 1, group 2, and group 3 (2.83 ± 0.66 mm, 1.5 ± 0.97 mm, 1.14 ± 0.89 mm, $P < 0.05$). The mean torque and ISQ values were 61.2 ± 13.9 Ncm and 77 ± 3.74.*

Conclusion: *Osseodensification can alter ridge dimensions and allow for ridge expansion. Greater expansion can be expected at the crest in narrow ridges with adequate trabecular bone volume. (Implant Dent 2019;00:1–7)*

Key Words: osseodensification, ridge expansion, bone spring-back effect, alveolar bone deformation

Adequate bone volume surrounding dental implants at the time of implant placement has been suggested as a contributing factor for stable periimplant bone levels.[1,2] Frequently, healed edentulous ridges serving as potential implant sites have inadequate dimensions to accommodate implant placement at restoratively appropriate positions.[3,4] Even when ridge preservation procedures are used at the time of tooth extraction, a relatively high proportion of sites may need additional regenerative procedures.[5]

Several techniques for the management of inadequate bone volume have been developed and evaluated.[6] Alveolar ridge expansion/splitting techniques have been attractive methods used to manage edentulous ridges with inadequate dimensions and, in many instances, allow for simultaneous implant placement. With these techniques, a series of osteotomes,[7] screw-type expanders, or chisels[8] have been used to locally expand or split the developing osteotomy site.

Recently, a novel method has been introduced for osteotomy preparation termed "osseodensification."[9] Osseodensification uses specially designed burs, which when running in reverse (counterclockwise rotation), will preserve bone bulk, facilitate compaction autografting, and deform bone, resulting in an outward strain from the osteotomy. This strain, if controlled, can result in plastic deformation and expansion of

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the alveolar bone. An elastic rebound and a spring-back effect were documented as a result of osseodensification.[9] Thus, after implant placement, the rebound of bone on the implant surface may increase the immediate to early bone-to-implant contact during healing, allowing for the autografted bone particulate to be held firmly against the implant. This improves the implant primary stability and potentially maintains higher stability values throughout the healing process.[9–12]

Another potentially beneficial effect of using osseodensification for osteotomy preparation is compaction autografting of bone. Fragments of preserved autogenous bone are pushed apically and laterally due to the counterclockwise motion of the bur.[9] This autogenous compacted graft within the osteotomy not only provides increased mechanical primary stability against the implant but can also serve as nucleation for vital new bone formation surrounding the implant.[10–12] This dually enhances the total implant stability during the early healing stage.[10–12]

The theoretical expansion of bone width dimensions during osteotomy creation with the osseodensification burs could allow for the reduction in surgical steps traditionally associated with guided bone regeneration (GBR) procedures, and for increased bone dimensions around the implant, as well as possible simultaneous GBR procedures with implant placement.

Thus, this study aims to evaluate the immediate ridge expansion values after the osseodensification method and the resulting implant primary stability.

MATERIALS AND METHODS

This study was designed as a retrospective multicenter case series. Patients who were treated with implant placement through osseodensification instrumentation for teeth replacement, between April 2014 and August 2015, were included from 4 treatment centers (Dept. of Periodontology at the University of Florida, Gainesville, FL, USA; Dept. of Periodontology at Virginia Commonwealth University, Richmond, VA, USA; private practice in Fort Lauderdale, FL, USA; and private practice in Jackson, MI, USA). All patients had to be in good general health and treatment planned for implant placement in a healed ridge. Operators followed standardized existing surgical and routine data collection protocols. These data included age, sex, implant location, smoking habits, intraoperative or postoperative complications, the presence of systemic disease, implant diameter and length, and radiographical analysis. The main outcome variable was the immediate alveolar ridge width changes after instrumentation. This retrospective analysis was observed in full accordance with the World Medical Association Declaration of Helsinki. All patients signed a consent form. The patients' specific files and data were kept confidential. The extracted data were assigned a random case number. The patients' initials were not used as case identifiers.

Surgical Technique

The implants used in the current study were obtained from a single manufacturer (Tapered Screw-Vent; Zimmer Biomet Dental, Palm Beach Gardens, FL).

On flap elevation and before osteotomy preparation, the alveolar ridge width was measured with standardized micro Castroviejo bone calipers at the

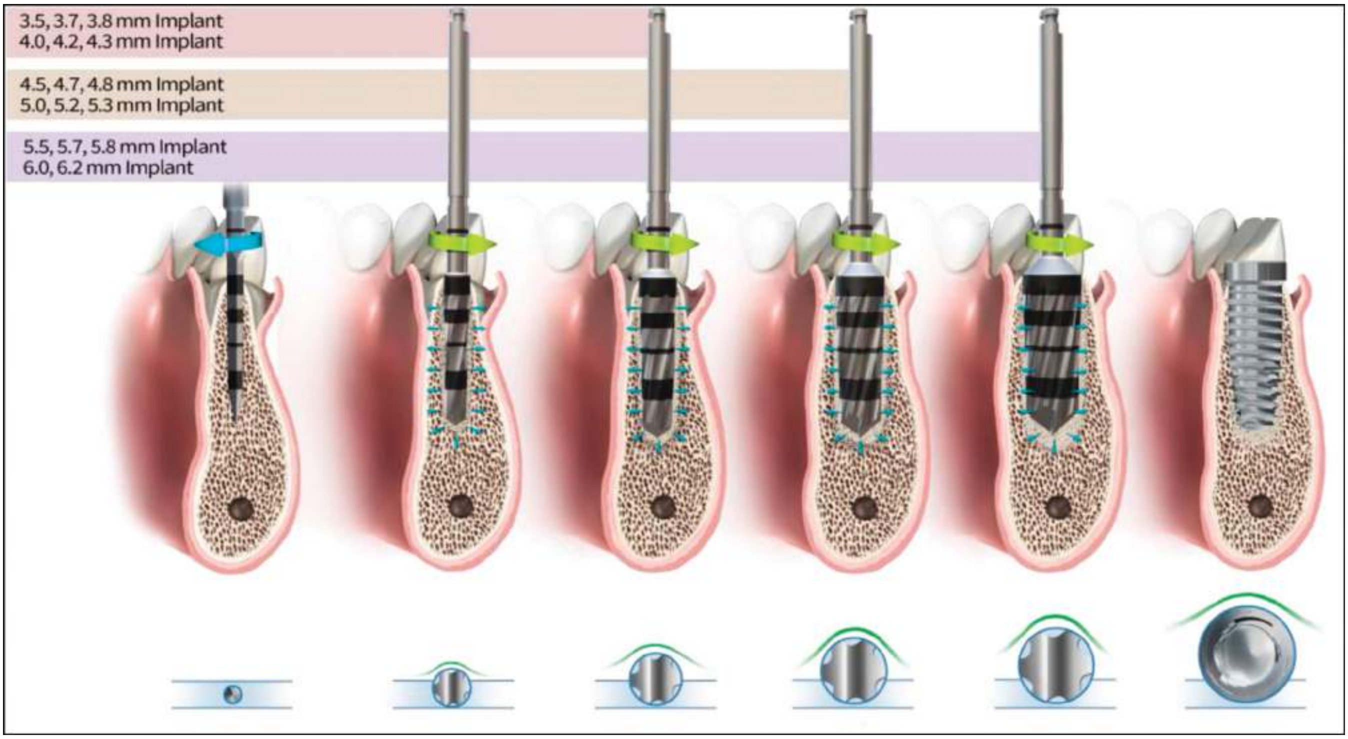

Fig. 1. Osseodensification burs were used in small increments of width increase. Small increasing width increments allow for controlled plastic deformation of bone tissue.

level of the crest and 10 mm apical from the crest. Osteotomy preparation began with 1.5-mm pilot osteotomy followed with osseodensification burs (Versah, LLC, Jackson, MI) in counterclockwise rotation at 900 to 1200 RPM with irrigation and with small increasing width increments (Fig. 1), and according to the manufacturing recommended protocol (www.versah.com). Immediately after the osteotomy preparation and before the implant placement, ridge width measurements were repeated. Implant diameter was selected to be equal or slightly wider (up to 0.7 mm wider) than the initial ridge width. After implant installation, additional hard and soft tissue grafting was performed when the resulting buccal bone thickness was less than 2 mm. When necessary, a 1-stage or 2-stage treatment protocol was performed based on the preference and clinical judgment of the operator. A representative clinical case is shown in Figure 2.

Implant Stability Assessment

At the time of the implant placement, the insertion torque was recorded with a manual torque device. Implant stability quotient (ISQ) values were measured with a resonance frequency analysis system (Ostell, Gothenburg, Sweden). For 16 implants, ISQ values were recorded again at 3 and 6 weeks during routine follow-up visits.

Statistical Analysis

For a description of the data, the mean values and SDs were calculated. The primary outcome variable was the immediate actual change in alveolar ridge width after osteotomy preparation with osseodensification burs. Following data collection, the authors created 3 group samples according to the initial alveolar ridge width as follows: group 1: 3 to 4 mm (n = 9), group 2: 5 to 6 mm (n = 12), and group 3: 7 to 8 mm (n = 7). Comparisons of alveolar ridge width changes between different groups were performed with the Student-Newman-Keuls test (analysis of variance). A *P* value of <0.05 was considered statistically significant.

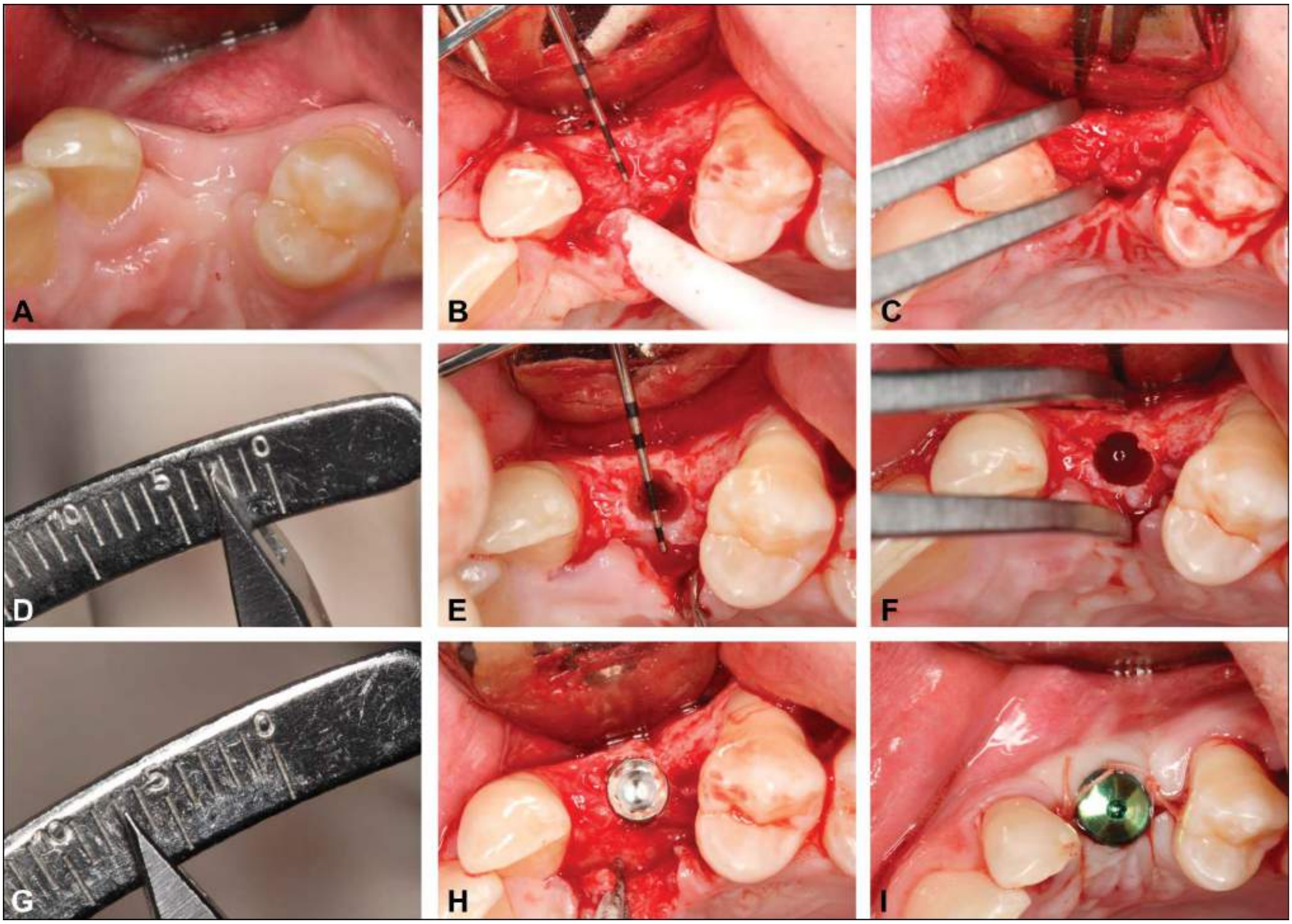

Fig. 2. A, Initial case presentation. Clinical occlusal view depicting a deficient ridge in area # 6. B–D, Ridge width measurements were done directly with bone calipers. Clinical occlusal view of the alveolar ridge width measurement at the crest. Ridge width measurement at 10 mm apical to the crest, before osteotomy preparation. E–G, Clinical view of the alveolar ridge width measurement at the coronal aspect of the ridge as well as at 10 mm apical to the crest with bone calipers, after osteotomy preparation with osseodensification burs. H, Clinical view of 3.7/13 mm implant was placed in 3-mm initial ridge width, after adequate ridge expansion with adequate insertion torque and ISQ value. Osseodensification will provide adequate expansion to place the implant within autogenous bony walls. I, Clinical palatal view of the site after bone and soft tissue grafts were done in the buccal before primary flap closure. Hard and soft tissue thickness is needed for long-term stability.

Table 1. Mean Alveolar Ridge Width Before and After Osteotomy Preparation in Millimeter

	Mean Alveolar Ridge Width in Millimeter (SD)					
	Group 1: 3–4 mm (n = 9)		Group 2: 5–6 mm (n = 12)		Group 3:7–8 mm (n = 7)	
	Coronal	Apical	Coronal	Apical	Coronal	Apical
Preexpansion	3.55 (0.46)	7.66 (1.41)	5.37 (0.43)	7.58 (0.73)	7.07 (0.53)	8.14 (1.67)
Postexpansion	6.38 (0.82)	8.66 (1.11)	6.87 (0.85)	8.45 (1.92)	8.2 (2.46)	9.28 (1.11)
Expansion value	2.83 (0.66)*†	1.0 (0.70)	1.5 (0.97)*	0.87 (0.90)	1.14 (0.89)†	1.14 (1.06)
% of expansion	75	13	27	14	17	17

There was a significant difference in the mean expansion value between groups 1, 2, and 3. The most significant expansion was evident in the (3–4 mm) group.
*$P < 0.05$ group 1 versus group 2 ANOVA with Bonferroni corrections.
†$P < 0.05$ group 1 versus group 3 ANOVA with Bonferroni corrections.
ANOVA, analysis of variance.

RESULTS

A total of 21 patients, 12 women and 9 men, who have received 28 implants simultaneously with ridge expansion through osseodensification, were included. Patients' average age was 53.7 ± 12.4 years, with a range of 28–80 years. Fifteen and 13 implants were placed in the maxilla and mandible, respectively. Twenty-six of the 28 implants survived and were successfully restored, resulting in a survival rate of 92.8%. Two implants failed, both at the 2-week post-op and both were in the mandible. Sites that failed were the right lower canine and second lower right premolar. At the lower right canine site, the initial ridge width was 5.5 mm at the crest and 6 mm at the base (10 mm apical to the crest); the resulting ridge expansion at the crest and apex was 1.5 and 1.0 mm, respectively. The torque and ISQ values at insertion were 60 Ncm and 70 ISQ. Importantly, at the time of implant installation, the buccal plate suffered from microfractures. For the lower right second premolar site, the initial ridge width measured 8 mm at the crest and 7 mm at the base (10 mm apical to the crest), and the resulting ridge expansion at the crest and apex was 1.0 and 0.0 mm, respectively. The insertion torque and ISQ values at placement were 80 Ncm and 79 ISQ. It was noted that both these sites had alveolar ridge geometry with a crest width that is relatively equal to the base width.

The overall mean initial width at the crest was 5.2 ± 1.4 mm, and the width at 10 mm apical to the crest was 7.8 ± 1.9 mm. After using the osseodensification method, the mean width of the bone at the crest was 7.1 ± 1.0 mm, and at 10 mm apical to the crest was 8.7 ± 1.5 mm. The resulting mean expansions at the crest and at 10 mm apically were 1.8 ± 1.1 mm and 0.9 ± 0.8 mm, respectively. The mean torque value at insertion was 61.2 ± 13.9 Ncm, and the mean ISQ value at insertion was 77 ± 3.74 ISQ. For implants with ISQ values measured at weeks 3 and 6, the mean values were 71.3 ± 3.29 ISQ and 75.3 ± 3.88 ISQ, respectively.

The results of the dimensional changes for the 3 groups are illustrated in Table 1. There was a significant difference in the mean expansion value at the coronal aspect of the ridge between group 1 (3–4 mm ridge) and group 2 (5–6 mm ridge) 2.83 ± 0.66 mm versus 1.5 ± 0.97 mm, $P < 0.05$, and between group 1 (3–4 mm ridge) and group 3 (7–8 mm ridge) 2.83 ± 0.66 mm versus 1.14 ± 0.89 mm, $P < 0.05$, as illustrated in Figure 3. There was no significant difference in the mean expansion value at the apical aspect between all groups, as illustrated in Figure 4.

Overall, the expansion in ridge dimensions was higher in the crestal region. Among the subdivided groups, the ridge dimensional percentage increase was greatest in group 1 (3–4 mm ridge) 75% expansion, followed by group 2 (5–6 mm ridge) 27% and lowest in group 3 (7–8 mm ridge) 17% expansion.

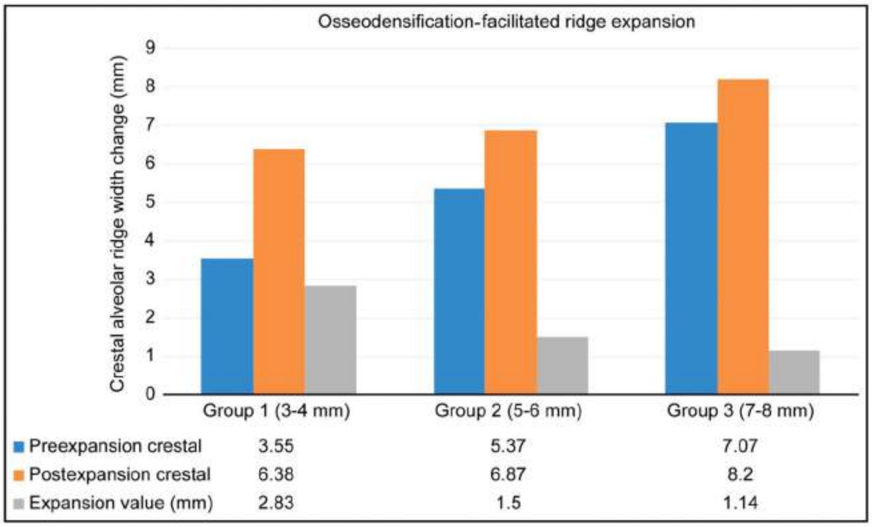

Fig. 3. Crestal bone expansion was evident. Significant difference was observed in the mean expansion value at the coronal aspect of the ridge between group 1, group 2, and group 3.

DISCUSSION

The results of this study demonstrated that changes occur in alveolar ridge dimensions when using osseodensification. The greatest ridge expansion occurred at the crest in sites with adequate trabecular bone volume and when the ridge was initially 3–4 mm (Figure 5). Several factors may

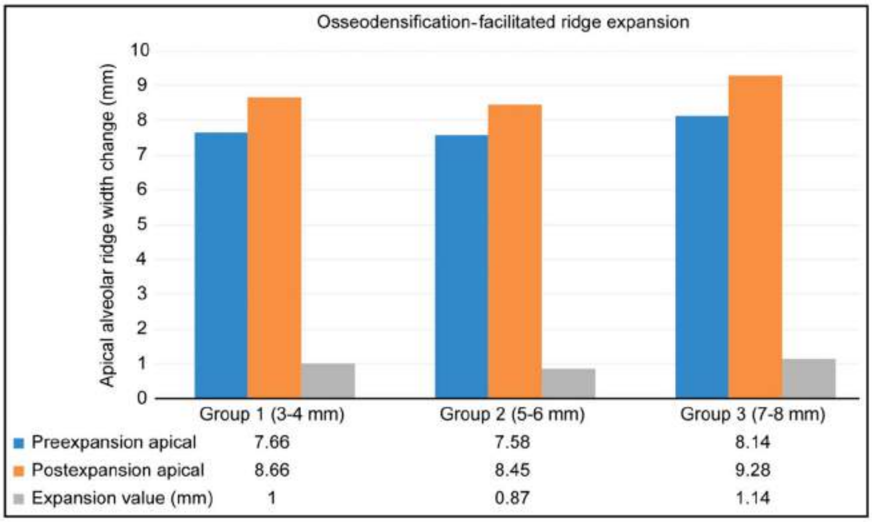

Fig. 4. Apical bone region expansion was significantly less than the crestal region. No significant difference was observed in the mean expansion value at the apical aspect of the ridge between the 3 groups.

explain the finding of greater crestal region expansion in comparison with the apical area of the osteotomy. Apically, the bone tapers out often resulting in more trabecular spaces to absorb the expansion strain without significant dimensional change and for the autografted particles to settle. By contrast, the crestal region may have relatively less trabecular spaces, which results in a limited ability to absorb the expansion strain applied by the densifying bur. Thus, resulting in more plastic deformation of the trabecular layer as long as the cortical layer surrounding it is sufficiently thin to allow for the physical expansion. In a histological study performed by Trisi et al,[10] it was demonstrated that sites with sufficient trabecular bone thickness prepared with osseodensification burs will plastically deform and outwardly expand, thus expanding the thin cortical bone layer with it. The density and the thickness of the cortical bone layer in relation to the trabecular bone volume is critical and dictates the plastic deformation and the expansion range. Crestal regions with higher proportions of cortical bone and lower volume of trabecular bone are less likely to undergo low plastic deformation and are more likely to fracture rather than expand.

The tapered shape of the densifying bur may also be another factor accounting for greater expansion of the crestal region compared with the apical region. The apical region is prepared with the narrower portion of the densifying bur and the crestal region with the wider portion of the bur. This results in greater strain at the crest. One issue that may arise is the possibility of crestal cortical bone microfracturing in sites with limited trabecular bone volume. Once the bone microfractures, a longer healing phase is required. If most of the implant stability is dependent on bone that has microfractures, then the turnover may result in an unstable failing implant.[13] It was observed that the minimum ridge width required for predictable plastic expansion through osseodensification is a 4-mm ridge with thicker trabecular bone volume surrounded by thinner cortical layers (Figure 5). More plastic expansion may occur in sites with a higher trabecular to cortical bone ratio.

Adequate diagnosis of bone volume, composition, structure, and clinical judgment must be used when using osseodensification-facilitated ridge expansion. The haptic feedback of the densifying burs with small increment expansion should be used to prevent excessive apical pressure. If macrofractures are noted or suspected, then tissue contour grafting is recommended, and 2-stage healing may be required.

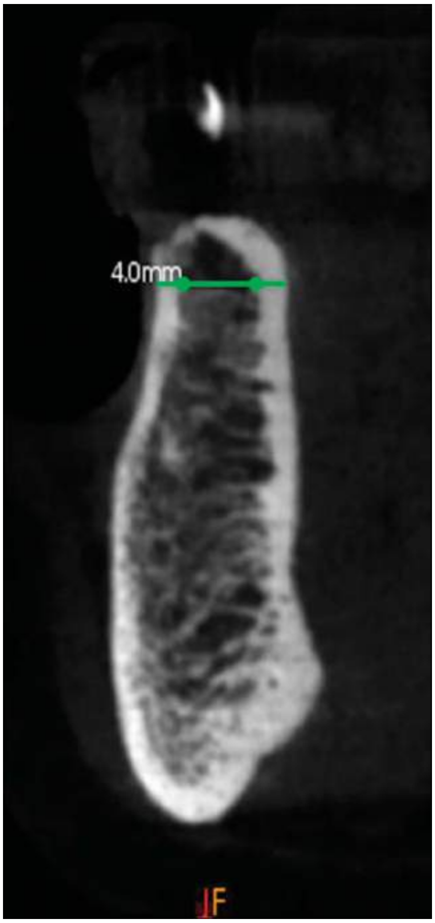

Fig. 5. Cone-beam computed tomography cross-section view depicting an example of the recommended minimum ridge for plastic expansion with osseodensification: 4-mm width with ≥2 mm trabecular bone core and 1-mm cortical plate thickness.

The hammered osteotome technique for ridge expansion is designed to plastically deform cortical and trabecular bone through the bone condensation method, resulting in a denser expanded osteotomy with more bone against the implant.[7] Osteotomy preparation with the osteotome technique also has the potential of creating microfractures.[14] Many studies demonstrating microfractures and implant failures with high torque values have obtained these torque levels by using undersized osteotomy preparation methods or with osteotomies produced with hammered osteotomes.[13,15] The undersized osteotomy protocol with standard drilling advocates for producing higher implant primary stability, measured with high insertion torque values, by preparing an undersized cylindrical osteotomy[16] to receive a wider tapered implant. This model tends to produce a lasting compression of bone tissue by the implant and may create microfractures and pressure necrosis of bone[16] specifically in the crestal region where there is usually, particularly in the mandible, a limited volume of trabecular bone and higher volume of cortical bone.

Osseodensification creates higher implant primary stability with higher insertion torque values through 2 different methods; the first method is compaction autografting of the osteotomy, which occurs as the native bone particulates are displaced into both the lateral and the apical trabecular spaces.[9] These autografted particles result in an additional bone volume that will contact the implant during insertion.[9–11] Second, the compacted bone into the internal walls of the osteotomy that have undergone elastic deformation will spring-back into the center resulting in higher implant stability.[9] These mechanisms of providing higher primary stability differ from that of the undersized osteotomy model. Therefore, there is no need to undersize the osteotomies with osseodensification. Rather, it is recommended to oversize the osteotomy in ridge expansion cases to prevent the implant thread from overstraining the expanded bone during the implant insertion.

Although data are limited on the ISQ values during the 3- to 6-week healing period, 16 cases have demonstrated continued stable ISQ values during the first 6 weeks of healing. This information suggests that stability of the implant is retained during the healing process rather than having a reduction in stability while remodeling occurs.[17] This finding can also be explained by the compacted autografting. The autogenous compacted bone particles serve as nucleation for new bone formation.[10–12] Thus, as bone turnover occurs, the graft particles can quickly turnover, resulting in a potentially seamless transition from primary to secondary stability.[11,12]

CONCLUSION

Based on this retrospective study, the following observations can be made: 2 implants have failed to integrate, there was expansion in all sites prepared with osseodensification, ISQ and their insertion torque appeared to be relatively high, greater expansion was observed in thinner ridges with adequate trabecular bone volume, and the expanded ridge allowed for implant placement in native bone with sufficient primary stability and potentially reduced the need for independent bone augmentation surgery. Alveolar ridge expansion by osseodensification in sites with cortical type I bone or in sites with a limited volume of trabecular bone as well as in a resorbed ridge site that is equally thin at the crest and the base may produce a higher risk of bone overstraining and microfractures. In these sites, it is recommended to develop the tissue volume with GBR before expansion with osseodensification.

Controlled clinical studies with larger sample size are required to further assess the efficacy of this technique and evaluate its patient-related outcome.

DISCLOSURE

S. Huwais states he is the founder of osseodensification and the inventor of the Densah Bur. All other authors claim to have no financial interest, either directly or indirectly, in the products or information listed in this article.

APPROVAL

Treatments and data collection were performed retrospectively according to standardized and routine treatment protocols. This retrospective analysis was observed in full accordance with the World Medical Association Declaration of Helsinki. All patients signed a consent form. The patients' specific files and data were kept confidential. The extracted data were assigned a random case number. The patients' initials were not used as case identifiers.

ROLES/CONTRIBUTIONS BY AUTHORS

T. Koutouzis: Co-first author, concept/design, data extraction and analysis, drafting of the article, critical revision, and final approval. S. Huwais: Co-first author, concept/design, data extraction and analysis, drafting of the article, critical revision, and final approval. F. Hasan: Concept/design, data interpretation, data extraction and analysis, drafting of the article, critical revision, and final approval. W. Trahan: Concept/design, data interpretation, data extraction and analysis, drafting of the article, critical revision, and final approval. T. Waldrop: Concept/design, data interpretation, data extraction and analysis, drafting of the article, critical revision, and final approval. R. Neiva: Concept/design, data interpretation, data extraction and analysis, drafting of the article, critical revision, and final approval.

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