ORIGINAL RESEARCH

Effect of Osseodensification on Bone Density and Crestal Bone Levels: A Split-mouth Study

Siddhant Aloorker[1], Manoj Shetty[2], Chethan Hegde[3]

Abstract

Background: Dental implants have become a popular alternative in the oral and maxillofacial rehabilitation after the introduction of the concept of osseointegration. A poor density bone can negatively influence the bone to implant contact (BIC) and delay osseointegration. Various osteotomy techniques and drilling procedures have been used to increase stability in low-density bone. But they have been associated with limitations such as trauma to the surrounding bone and difficulty in controlling the technique. Osseodensification has recently been developed. Densifying burs are specifically designed burs which help in preserving the bone by condensing the bone by rotating in the noncutting direction.

Materials and methods: Split-mouth study was conducted on a total of 10 patients wherein implants were placed in the same patient bilaterally in maxillary posterior region where the left maxillary posterior region received implants through sequential osteotomy technique and the right maxillary posterior region received implants through a series of new multifluted tapered burs (Densah™). A cone-beam computed tomography (CBCT) was taken preoperatively, immediately after implant placement, and 3 and 6 months after implant placement. The bone density and crestal bone levels were measured. Results were analyzed by student's paired "*t*" test and Man-Whitney *U* test.

Results: There is no statistical difference between the levels of the crestal bone between an osseodensified site as compared to a conventional osteotomy site. The width of the residual bone increases after osseodensification and remains in the increased dimension for 3 months and continues at 6 months. Thus, it can be concluded that osseodensification leads to bone expansion.

Conclusion: The radiographic bone density adjacent to the implant is significantly increased after ossedensification and the bone there remains relatively dense over a period of 6 months aiding in a primary stability and eventual good osseointegration.

Keywords: Bone density, Dental implant, Osseointegration.

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Introduction

Dental implants have become a popular alternative in the oral and maxillofacial rehabilitation after the introduction of the concept of osseointegration. The volume and quality of the bone present at the site are important factors determining the type of surgical procedure and the type of the implant, and they are related to the success of dental implant surgery.[1] Maxilla and mandible present a wide variation in respect to the bone density and the type of bone present in different regions. A poor density bone, such as in the maxillary posterior region, can negatively influence the bone to implant contact and delay osseointegration.[2,3] A regular sequential osteotomy removes a considerable amount of bone to make the preparation enough to receive an implant with decided diameter. This may be deleterious in a condition where the bone is soft or the density of the bone is poor such as in maxillary posterior region. Therefore, a new osteotomy preparation technique, osseodensification, has recently been developed.[4,5] Densifying burs are specifically designed to preserve the bone. Instead of rotating clockwise, they rather rotate anticlockwise which compacts and autografts the bone within the socket itself thereby reducing the amount of the bone lost. This autografting of the bone also helps to increase the density of the bone by condensing the bone by rotating in the noncutting direction. This improves the quality and quantity of the bone around the implants in the areas such as maxillary posterior region where the bone is soft.[6,7] A study was done by Sultana et al. in the anterior maxilla where traditional and OD drilling were compared. They found that there were higher levels of primary stability in the OD drilling site.[8] There is no study comparing the OD and conventional drilling in the same patient. Hence this split-mouth study was done with an aim to compare the osseodensification technique and conventional drilling technique in maxillary posterior regions. Hence, this study included assessing the effects of these osteotomy techniques on maxillary posterior region as this region has softer bone, and thus densifying the area during placement might lead to improved prognosis.

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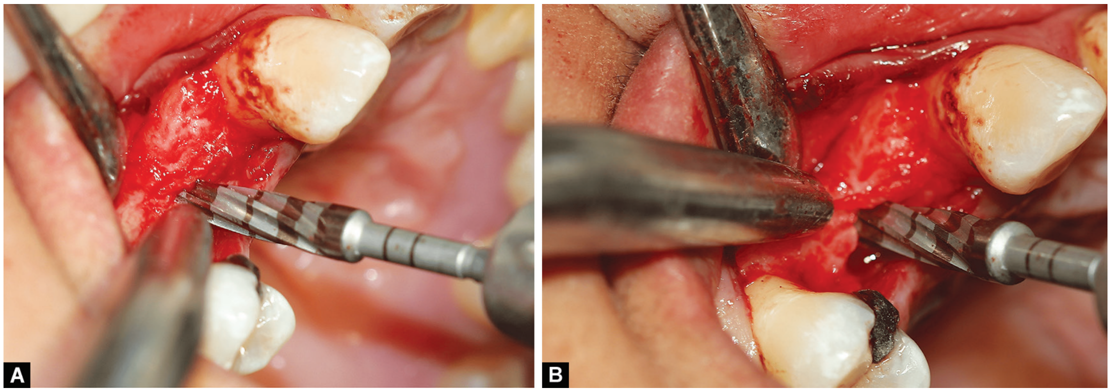
Materials and Methods

The study was conducted on subjects visiting outpatient Department of Prosthodontics and Crown and Bridge and Department of Oral Implantology. Approval from Institutional Ethical committee was obtained. Informed consent was obtained from each subject.



Figs 1A and B: Osseodensification with versah

Inclusion Criteria

All patients requiring tooth replacement in the posterior maxillary region bilaterally with bone height in the range of 11–16 mm and bone width of 4.5–5.5 mm.

Exclusion Criteria

All patients with diabetes mellitus, hypertension, any soft or hard tissue pathology, parafunctional oral habits such as bruxism, smoking, and limited mouth opening will be excluded.

Sample Size Estimation

$$n = 2\,(Z\alpha + Z\beta)^{2\,*}\,S^2$$

where $Z\alpha = 1.96$ at 95% confidence level and
$Z\beta = 0.84$ at 80% power
S = combined standard deviation
d = mean difference

With 95% confidence level and 80% power, sample size comes to to be a minimum of 10 in each group[3]

$$d = 49.58–46.19 = 3.39,\ s = 2.8$$

Thus 10 samples of each group were taken for implant placement and analysis:

Group I: with osseodensification in the left maxillary posterior region
Group II: with conventional drilling in the right side of the maxillary posterior region

Study Design

Split-mouth study

At initial visit, screening and examination of patients based on the criteria planned for implant placement bilaterally for a split-mouth study.

Session 2: Preoperative radiographic examination (orthopantomogram) and CBCT and diagnostic impression for fabrication of thermoplastic stent.

Session 3: Bilateral implant placement (group I and group II) and CBCT assessment for crestal bone levels and bone density.

Session 4: Three-month postimplant placement, CBCT assessment for bone density, and crestal bone levels.

Preoperative investigation

Orthopantomogram was used to analyze the native bone in the edentulous area. Blood investigations were conducted to ensure normal levels are attained.

Surgical Protocol

Surgery commenced after the administration of prophylactic antibiotic regimen (Misch's Protocol). Two edentulous sites were selected at random for the desired treatment plan. The implants were placed in both the sites in a single appointment. Patient was prepared and long-acting local anesthesia was administered (2% lidocaine with 1:80,000 adrenaline). A mid crestal incision was given and a full-thickness mucoperiosteal flap was elevated. One site was prepared using osseodensification procedure (Fig. 1) where the implant site was prepared through osseous extraction drilling technique by anticlockwise rotation of the burs, and the contralateral site was prepared using conventional drilling. Both sites received threaded SLA implants. The surgical site was closed and patient was advised to use chlorhexidine gluconate mouthwash thrice daily for two weeks to reduce plaque formation.

A small field of view CBCT scans of the area of concern preoperatively were taken, immediately after placement and at 3 months postoperatively and 6 months postoperatively. Radiographically the changes in bone density and crestal bone levels at region around first two threads and last two threads of the implant were assessed at different time intervals for left and right sides.

It was evidenced that the bone density had increased during immediate postoperative CBCT; this further prompted the use of 3 months CBCT to evaluate the density after the healing period. This further warranted the use of CBCT post loading to analyze if the bone changes after being subjected to axial loads.

The bone density and crestal bone levels were measured using PLANMECA ROMEXIS® software. The measuring tool in the software where crestal bone levels were analyzed by the levels of the bone at the crest of the bone (first and second threads) and at the apical thirds (last two threads). A horizontal line was drawn on the most apical part of the implant. A vertical line was drawn from that point till the first bone contact on each buccal, lingual, mesial, and distal side from that vertical line horizontal lines were drawn to analyze the level of bone at the first tow threads and last two threads (Fig. 2).

Statistical analysis was done using student's paired "*t*" test and Man-Whitney *U* test.

Results

Comparison of Crestal Bone Levels—Height at Different Time Intervals

Crestal bone levels of height were measured at different time intervals in both left and right sides. The mean crestal bone levels

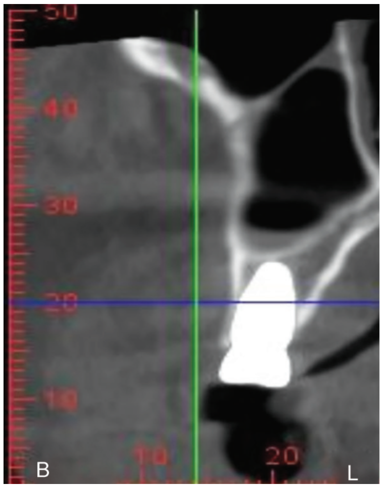


Fig. 2: CBCT section showing bone contours and density drill

Table 1: Comparison of crestal bone levels—height at different time intervals

	Left		*Right*	
	Mean	*Standard deviation*	*Mean*	*Standard deviation*
Pre-op	14.867	2.047	14.412	2.007
Post-op	13.971	2.255	13.810	1.919
3 months follow-up	13.345	2.057	13.411	1.901
F	1.3		0.673	
p	0.289		0.519	

height of left at pre-level was found to be 14.867 and that of post level it reduces to 13.971 and again it decreased to 13.345 at the 3 months follow-up. Similarly at right side also the mean value at pre-level was 14.412 which is comparatively less with that of left side. Here at post level the value decreased to 13.81 and again to 13.411 at 3 months follow-up. But in both left and right sides the decrease from pre till the follow-up was not found to be statistically significant which was seen as $p > 0.05$ (Table 1).

Comparison of Crestal Bone Levels—Width at Different Time Intervals

Even the crestal bone levels width were not showing any significant difference at different time intervals either in the left or right side. The mean value of the width of left at pre-level was 8.401 and reduced to 8.199 at post-op level. It further reduced to 7.86 at 3-month follow-up. But the difference of this mean reduction among this three time intervals was not statistically significant ($p = 0.133$). But on the right side the mean width at pre-level was 8.664 and increased to 9.189 at post-op level. But again it reduced to mean of 8.963 at 3 months follow-up but still it showed the increase from the pre-level. Here also the difference among the time interval was not showing statistical significant ($p = 0.124$) (Table 2).

Comparison of Radiographic Bone Density (in HU)—First Two Threads at Different Time Intervals

Radiographic bone density (in HU) for first two threads was estimated at left and right sides at different time intervals. Here we could clearly see that the mean radiographic bone density in first two threads was significantly different in right side and not significant in left side. The mean bone density at pre-level in left side was 472.60 and increased to 501.50 at post-op and again decreased to 449.80 at 3-month follow-up. But the difference in their mean value is not statistically significant ($p = 0.234$). But on the other hand, on right side, the mean density was 463.40 at pre-level and increased to 746.50 at post-op and decreased at 3 months follow-up having mean of 649.700. This comparison of mean score at different time interval was found to be statistically significant ($p < 0.001$) (Table 3).

Table 2: Comparison of crestal bone levels—width at different time intervals

	Left		*Right*	
	Mean	*Standard deviation*	*Mean*	*Standard deviation*
Pre-op	8.401	0.709	8.664	0.502
Post-op	8.199	0.545	9.189	0.551
3 months follow-up	7.860	0.481	8.963	0.605
F	2.172		2.256	
p	0.133		0.124	

Table 3: Comparison of radiographic bone density (in HU)—first two threads at different time intervals

	Left		*Right*	
	Mean	*Standard deviation*	*Mean*	*Standard deviation*
Pre-op	472.60	79.626	463.40	64.845
Post-op	501.50	61.009	746.50	96.444
3 months follow-up	449.80	55.541	649.70	91.493
F	1.532		23.766	
p	0.234		<0.001***	

***Very highly significant

Comparison of Radiographic Bone Density (in HU)—First Two Threads—Intercomparison

On the left side, there was no statistical significance we could see with the overall comparison at different time levels. Hence there was no significant at intercomparison also. But on the right side, the mean bone density from pre- to post-op was increased to 283.1 and was found to be statistically significant by applying the test for repeated measures Bonferroni *t*-test. The increase from pre- to 3-month follow-up was also 186.3 and found to be statistically significant ($p = 0.085$) (Table 3A).

Comparison of Radiographic Bone Density (in HU)—Last Two Threads at Different Time Intervals

The mean values of radiographic bone density of last two threads were also compared for right and left side for different time intervals. At left side the mean radiographic bone density for last two threads was 461.50 at pre-level and increased to 504.30 at post-op level. But during the 3-month follow-up the mean value decreased to 445.10. But the difference at these time intervals was not significant ($p = 0.129$). At right side the mean difference from pre- to post-op is very large and the mean value increased to 780.20

Table 3A: Comparison of radiographic bone density (in HU)—first two threads—intercomparison

Difference from			*Mean difference*	*p*
Left	Pre	Post-op	−28.9	1.000
		3-month follow-up	22.8	1.000
	Post-op	3-month follow-up	51.70	0.276
Right	Pre	Post-op	−283.1	<0.001***
		3-month follow-up	−186.3	<0.000***
	Post-op	3-month follow-up	96.80	0.085

***Very highly significant

Table 4: Comparison of radiographic bone density (in HU)—last two threads at different time intervals

	Left		*Right*	
	Mean	*Standard deviation*	*Mean*	*Standard deviation*
Pre-op	461.50	77.885	494.0	65.901
Post-op	504.30	60.318	780.20	47.109
3 months follow-up	445.10	54.378	703.50	65.680
F	2.214		60.539	
p	0.129		<0.001***	

***Very highly significant

Table 4A: Comparison of radiographic bone density (in HU)—last two threads—intercomparison

Difference from			*Mean difference*	*p*
Left	Pre-op	Post-op	−42.80	0.457
		3-month follow-up	16.40	1.000
	Post-op	3-month follow-up	42.80	0.457
Right	Pre-op	Post-op	−286.20	<0.001***
		3-month follow-up	−209.50	<0.000***
	Post-op	3-month follow-up	76.70	0.085

***Very highly significant

from the pre value of 494.00. Then at 3 months follow-up the value decreased to 703.50. And this difference was found to be statistically significant (p <0.001) (Table 4).

Comparison of Radiographic Bone Density (in HU)—Last Two Threads—Intercomparison

Intercomparison among the time interval was done by Bonferroni *t* test. At left side there was no difference among the post-op and follow-up from pre value and hence even intercomparison between these timings was not significant. But at right side there was an increase of 286.5 from pre- to post-op and 209.5 from pre- to 3 months follow-up. Both differences were found to be statistically significant (p <0.01) whereas the difference from post-op to 3-month follow-up was not significant (p = 0.085) with the mean difference of 76.7 (Table 4A).

Comparison of Crestal Bone Levels Height between the Sides

While comparing the crestal bone levels height between right and left sides in all the three time intervals, it was found to be statistically insignificant. Here pre values of both left and right sides are 14.817 and 14.412, respectively. Similarly post-op the difference was only 0.161 between the two sides and not significant. Even at 3-month follow-up the mean crestal bone level height was 13.345 and that of right side was 13.411, and this difference of 0.066 was not statistically significant (Table 5).

Comparison of Crestal Bone Levels Width between the Sides

Comparison of crestal bone levels width at pre-level between right and left side was not significant. The mean pre value of left was 8.401 and that of right was 8.664, and this difference was not found to be significant by using students unpaired *t* test (p = 0.351). But after the post-op there was decrease in the mean value at left side, but at right side, there was increase in the mean value and this difference between right and left sides was found to be very highly significant (p <0.001) (Table 6).

Comparison of Radiographic Bone Density (in HU)—First Two Threads between the Sides

Radiographic bone density at first two threads was found to be significantly different between right and left sides at post-op and 3 months follow-up level. At pre-level there was not much difference between the mean value at left and right sides. At post-op the mean bone density was 501.5 at the left side and 746.5 at the right side, and while comparing the difference between these two sides, it was found that there was statistically significant difference between these two sides (p <0.001) (Table 7).

Comparison of Radiographic Bone Density (in HU)—Last Two Threads between the Sides

Radiographic bone density at last two threads was compared between the right and left sides, respectively, at pre-, post-op, and 3 months follow-up. At pre-level there was not much difference between the mean values (p = 0.327). But at post-op the increase from pre is more in right side than left side. The mean bone density at left side was 504.3 whereas on right side it was 780.2, and this difference was found to be statistically significant (p <0.001). Similarly at 3 months follow-up the mean bone density again reduced to 445.1 at left side and 703.5 at right side. Again the mean difference between right and left sides was showing very highly significant (Table 8).

Discussion

Implant primary stability comes out as one of the most essential prerequisites for gainful osseointegration.[5] There have been numerous techniques tested in the past to step up the implant primary stability in a bone with low density. Some of the studies demonstrated use of under preparation of the implant bed,[9] stepped osteotomy for the implant bed,[10] and the use of condensers and osteotomes.[11] These techniques have shown substantial amount of success, but they also had their own shortcomings. According to Lekholm and Zarb, a poor density bone, that is (D3–D4 type), is usually seen in the maxillary posterior regions. Due to the available bone having low density, the implant placed has the primary stability which is generally below the acceptable minimum values. This resultant is implants having low success rates which are placed in these sites.[12]

A new technique was introduced by Huwais in 2015, which was termed as osseodensification where specially designed bone osteotomy drills (Densah™ burs) were used.[13] Osseodensification condenses the bone using anticlockwise rotations. As it also provides

Table 5: Comparison of crestal bone levels height between the sides

	Left		*Right*			
	Mean	*Standard deviation*	*Mean*	*Standard deviation*	*t*	*p*
Pre-op	14.867	2.047	14.412	2.007	0.502	0.622
Post-op	13.971	2.255	13.810	1.919	0.172	0.865
3 months follow-up	13.345	2.057	13.411	1.901	0.075	0.941

Table 6: Comparison of crestal bone levels width between the sides

	Left		*Right*			
	Mean	*Standard deviation*	*Mean*	*Standard deviation*	*t*	*p*
Pre-op	8.401	0.709	8.664	0.502	0.957	0.351
Post-op	8.199	0.545	9.189	0.545	4.04	0.001***
3 months follow-up	7.860	0.481	8.963	0.605	4.51	0.001***

***Very highly significant

Table 7: Comparison of radiographic bone density (in HU)—first two threads between the sides

	Left		*Right*			
	Mean	*Standard deviation*	*Mean*	*Standard deviation*	*t*	*p*
Pre-op	472.600	79.626	463.400	64.845	0.283	0.78
Post-op	501.500	61.009	746.500	96.444	5.894	0.001***
3 months follow-up	449.800	55.541	649.700	91.493	5.906	0.001***

***Very highly significant

Table 8: Comparison of radiographic bone density (in HU)—last two threads between the sides

	Left		*Right*			
	Mean	*Standard deviation*	*Mean*	*Standard deviation*	*t*	*p*
Pre-op	461.500	77.885	494.000	65.901	1.007	0.327
Post-op	504.300	60.318	780.200	47.109	11.40	0.001***
3 months follow-up	445.100	54.378	703.500	65.690	9.583	0.001***

***Very highly significant

the tactile control with less traumatic compaction as opposed to an ostetome and mallet, the risk of causing microfractures is reduced.[14] These specially designed osteotomy drills has four or more lands which had a negative rake angle thus making the edges of these drills noncutting, and hence, a smoothly compact bone was generated. These osteotomy drills had a tapered shank along with a cutting chisel edge. They could hence engage deeper into the osteotomy site, at the same time by progressively increasing diameter of the osteotomy drill facilitated in gradual expansion of the bone at the surgical site. When used in a clockwise rotation direction (Cutting mode), the drills could be used to drill into the bone till adequate depth of the osteotomy was achieved.[15] Following this mode of the osteotomy site preparation, the rotation was then changed to counterclockwise direction (densifying mode), which caused the formation of a dense as well as strong and layer of the bone tissue along the lateral walls and the base of the osteotomy site. This technique also led to burnishing of the bone along the innermost layer of the prepared osteotomy site through controlled deformation of the bone surface.[16] Hence the eventual purpose of this procedure was to create a well condensed layer of bone which was autografted along the peripheral lateral walls and apical portion of the implant. In turn, this enhanced and increased the insertion torque values due to the increase in bone-implant contact, eventually, leading to a good implant primary stability.[9,12,17–19]

The osteogenic parameters along the surface of the implants were assessed by measuring the BIC and the growth of bone within the space between the implant threads as a percentage, called bone area fraction (BAF).[20–22] Many animal studies have also confirmed this fact.[1,4,20,22] A study carried out in sheep iliac crests concluded that osseodensification increases the bone to implant contact and increases the bone density adjacent to the osteotomy thus aiding in a better primary stability of the implant as compared to the areas with conventional osteotomy preparation.[4]

Studies were carried out by Hindi et al. where they compared the implant stability and bone density after osseodensification, and they noticed in increased implant stability.[23–25] Study done by Seo et al. also showed similar results.[26]

In the present study, radiographic bone density at first two threads was found to significantly differ between right and left sides postoperatively and 6 months follow-up intervals. Preoperatively there was no much difference between the mean value at left and right sides. Postoperatively the mean bone density was 501.5 HU at left side and 746.5 HU at the right side, and while comparing the difference between these two sides, it was found that there was statistically significant difference between these two sides (p <0.001). Same result could be seen at the 3 months follow-up where at left side the mean density was 449.8 HU and at right side it was 649.7 HU, which was a very huge difference and it was found to be statistically very highly significant (p <0.001). Similar results were seen at 6 months follow-up interval. Radiographic bone density at last two threads was compared between the right and left sides, respectively, preoperatively, postoperatively, 3 months follow-up, and 6 months follow-up. Preoperatively there was no much difference between the mean values (p = 0.327). But postoperatively right side increased values than the left side. The mean bone density at left side was 504.3 HU whereas on right side it was 780.2 HU, and this difference was found to be statistically significant (p <0.001). Similarly at 3 months follow-up, the mean bone density again reduced to 445.1 HU at left side and 703.5 HU at right side. Again, the mean difference between right and left side was showing a very high statistical significance. It can be noted that the bone densification achieved postoperatively remained relatively same after 3 months since there was no statistically significant difference in the two values (p >0.05). It was also noted that after 6 months follow-up the density had not changed significantly and had remained almost same.

A greater degree of osseointegration was expected in the surgical sites with a greater BIC and BAF. This could be attributed to the fact that the osteoblasts were nucleating on instrumented bone which is in close approximation with the implant surface.[4,26] Due to the presence of a layer of autografted bone around the implants in the area of osseodensification, the proximity allowed a quicker rate of osseointegration process.[27]

Limitations of the Study

Since these measurements of the structural connection between the implant body and the bone are histologic in nature, direct measurement connection's functionality was not possible.

The technique of osseodensification might be needed to be used with precaution in the areas like the mandibular anterior region where the bone is mostly cortical or it is dense. And again, the osteotomy drills employed for osseodensification have been found to raise the temperature, and this may result in neighboring osteoblasts getting necrosed, if these drills are not used with copious and abundant saline irrigation.[28]

Conclusion

Within the limitations of the study, it can be concluded that there is no statistical difference (p >0.05) between the levels of the crestal bone between an osseodensified osteotomy site as compared to a conventional osteotomy site.

Radiographic bone density adjacent to the implant is significantly increased after osseodensification and the bone there remains relatively dense over a period of 6 months aiding in a primary stability and eventual good osseointegration.

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References

1. Huwais S, Meyer EG. A novel osseous densification approach in implant osteotomy preparation to increase biomechanical primary stability, bone mineral density, and bone-to-implant contact. Int J Oral Maxillofac Implants 2017;32(1):27–36. DOI: 10.11607/jomi.4817.
2. Isoda K, Ayukawa Y, Tsukiyama Y, et al. Relationship between the bone density estimated by cone-beam computed tomography and the primary stability of dental implants. Clin Oral Implants Res 2012;23(7):832–836. DOI: 10.1111/j.1600-0501.2011.02203.x.
3. Cassetta M, Stefanelli LV, Pacifici A, et al. How accurate is CBCT in measuring bone density? A comparative CBCT-CT in vitro study. Clin Implant Dent Relat Res 2014;16(4):471–478. DOI: 10.1111/cid.12027.
4. Trisi P, Berardini M, Falco A, et al. New osseodensification implant site preparation method to increase bone density in low-density bone: In vivo evaluation in sheep. Implant Dent 2016;25(1):24. DOI: 10.1097/ID.0000000000000358.
5. Lioubavina-Hack N, Lang NP, Karring T. Significance of primary stability for osseointegration of dental implants. Clin Oral Implant Res 2006;17(3):244–250. DOI: 10.1111/j.1600-0501.2005.01201.x.
6. Parsa A, Ibrahim N, Hassan B, et al. Bone quality evaluation at dental implant site using multislice CT, micro-CT, and cone beam CT. Clin Oral Implants Res 2015;26(1):e1–e7. DOI: 10.1111/clr.12315.
7. Liang X, Lambrichts I, Sun Y, et al. A comparative evaluation of cone beam computed tomography (CBCT) and multi-slice CT (MSCT). Part II: on 3D model accuracy. Eur J Radiol 2010;75(2):270–274. DOI: 10.1016/j.ejrad.2009.04.016.
8. Sultana A, Makkar S, Saxena D, et al. To compare the stability and crestal bone loss of implants placed using osseodensification and traditional drilling protocol: a clinicoradiographical study. J Indian Prosthodont Soc 2020;20(1):45. DOI: 10.4103/jips.jips_133_19.
9. Ivanoff CJ, Grondahl K, Bergstrom C, et al. Influence of bicortical or monocortical anchorage on maxillary implant stability: a 15-year retrospective study of Branemark System implants. Int J Oral Maxillofac Implants 2000;15(1):103. PMID: 10697944.
10. Degidi M, Daprile G, Piattelli A. Influence of underpreparation on primary stability of implants inserted in poor quality bone sites: an in vitro study. J Oral Maxillofac Surg 2015;73(6):1084–1088. DOI: 10.1016/j.joms.2015.01.029.
11. Gomez-Roman G, Kruppenbacher M, Weber H, et al. Immediate postextraction implant placement with root-analog stepped implants: surgical procedure and statistical outcome after 6 years. Int J Oral Maxillofac Implant 2001;16(4):503–513. PMID: 11515997.
12. Fugazzotto PA, Wheeler SL, Lindsay JA. Success and failure rates of cylinder implants in type IV bone. J Periodontol 1993;64(11): 1085–1087. DOI: 10.1902/jop.1993.64.11.1085.
13. Jaffin RA, Berman CL. The excessive loss of Branemark fixtures in type IV bone: a 5-year analysis. J Periodontol 1991;62(1):2–4. DOI: 10.1902/jop.1991.62.1.2.
14. Herrmann I, Lekholm U, Holm S, et al. Evaluation of patient and implant characteristics as potential prognostic factors for oral implant failures. Int J Oral Maxillofac Implant 2005;20(2):220–230. PMID: 15839115.
15. Friberg B, Jemt T, Lekholm U. Early failures in 4,641 consecutively placed Branemark dental implants: a study from stage 1 surgery to the connection of completed prostheses. Int J Oral Maxillofac Implant 1991;6(2):142–146. PMID: 1809668.
16. Norton MR. The influence of insertion torque on the survival of immediately placed and restored single-tooth implants. Int J Oral Maxillofac Implant 2011;26(3):1333–1343. PMID: 22167441.
17. Alghamdi H, Anand PS, Anil S. Undersized implant site preparation to enhance primary implant stability in poor bone density: a prospective clinical study. J Oral Maxillofac Surg 2011;69(12):506–512. DOI: 10.1016/j.joms.2011.08.007.
18. Blanco J, Suarez J, Novio S, et al. Histomorphometric assessment in cadavers of the periimplant bone density in maxillary tuberosity following implant placement using osteotome and conventional techniques. Clin Oral Implant Res 2008;19(5):505–510. DOI: 10.1111/j.1600-0501.2007.01505.x.
19. Penarrocha M, Perez H, Garcia A, et al. Benign paroxysmal positional vertigo as a complication of osteotome expansion of the maxillary alveolar ridge. J Oral Maxillofac Surg 2001;59(1): 106–107. DOI: 10.1053/joms.2001.19307.
20. Wang L, Wu Y, Perez KC, et al. Effects of condensation on peri-implant bone density and remodeling. J Dent Res 2017;96(4):413–420. DOI: 10.1177/0022034516683932.

21. Kanathila H, Pangi A. An insight into the concept of osseodensification-enhancing the implant stability and success. J Clin Diagn Res 2018;12(7):ZE01–ZE03. DOI: 10.7860/JCDR/2018/35626.11749.
22. Slete FB, Olin P, Prasad H. Histomorphometric comparison of 3 osteotomy techniques. Implant Dent 2018;27(4):424–428. DOI: 10.1097/ID.0000000000000767.
23. Lopez CD, Alifarag AM, Torroni A, et al. Osseodensification for enhancement of spinal surgical hardware fixation. J Mech Behav Biomed Mater 2017;69:275–281. DOI: 10.1016/j.jmbbm.2017.01.020.
24. Hindi AR, Bede SY. The effect of osseodensification on implant stability and bone density: a prospective observational study. J Clin Exp Dent 2020;12(5):e474–e478. DOI: 10.4317/jced.56727.
25. Pai UY, Rodrigues SJ, Talreja KS, et al. Osseodensification–a novel approach in implant dentistry. J Indian Prosthodont Soc 2018;18(3):196–200. DOI: 10.4103/jips.jips_292_17.
26. Seo D-J, Moon S-Y, You J-S, et al. The effect of under-drilling and osseodensification drilling on low-density bone: a comparative ex vivo study. Appl Sci 2022;12:1163. DOI: 10.3390/ app12031163.
27. Johnson EC, Huwais S, Olin PS. Osseodensification increases primary implant stability and maintains high ISQ values during first six weeks of healing. In: Presentation at the American Academy of Implant Dentistry 63rd annual meeting. 2014.
28. Gaspar J, Esteves T, Gaspar R, et al. Osseodensification for implant site preparation in the maxilla-a prospective study of 97 implants. Clin Oral Implant Res 2018;29:163. DOI: 10.1111/clr.48_13358.