Osseodensification — A systematic review and qualitative analysis of published literature

Ninad Milind Padhye^{a,*}, Ashvini Mukul Padhye^b, Neel B. Bhatavadekar^c

^a Private Practitioner, Ceramco Dental Care, Mumbai, Maharashtra, India

^b Professor & Head of Department of Periodontics, Mahatma Gandhi Mission's Dental College and Hospital, Navi Mumbai, Maharashtra, India

^c Clarus Dental Specialties, Pune. Adjunct Faculty, University of North Carolina at Chapel Hill, USA

ARTICLE INFO

Keywords:

Dental implant
Implant stability
Implant primary stability
Osseodensification

ABSTRACT

The recently introduced technique of osseodensification for dental implant involves the use of special drills (Densah) run in a counter-clockwise direction at the osteotomy site. It is claimed that this causes expansion of the osteotomy site, and increases density of the bone in immediate vicinity of the osteotomy. We reviewed published papers on the primary stability attained using this drilling technique. As a secondary finding, the bone to implant contact (BIC) and the bone area fraction occupancy (BAF) was also compared between the conventional drilling protocol and the osseodensification protocol, among these articles. A Systematic search was performed in PubMed-Medline, Embase and Google Scholar for clinical/animal studies up to November 2018. A total of 12 articles, from a database of 132 articles, consisting of 8 animal histologic studies, 2 human based clinical studies, 1 case series and 1 case report were assessed. 10/12 articles measured the insertion torque values, 7/12 articles measured the BIC and 6/12 articles estimated the BAF between the two techniques. Quality assessment of 8 studies performed using ARRIVE guidelines showed that 6/8 studies had a high score. An average increase in the insertion torque, BIC and BAF was noted in the osseodensification group as compared to the conventional drilling group. Since most of these studies are non-clinical, it can be inferred that osseodensification is an efficient way to enhance primary stability of implants in low density bone in an animal model. However, extrapolation to long term clinical success cannot be ascertained until further evidence becomes available.

1. Introduction

Dental implants have revolutionized the field of oral rehabilitation. Having a success rate of over 90% over 10 years,¹ endosseous implants can now be successfully and predictably used to replace a missing tooth in the oral cavity. Osseointegration is the direct structural and functional connection between living bone and the titanium implant surface and is considered a prerequisite for implant loading.² Criteria for implant success were enlisted by Albrektsson et al., in 1981³.

1. Implant related factors – Biocompatibility,⁴ surface topography,⁵ composition,⁶ shape, design, dimensions^{7,8} etc.
2. Host related factors – Bone quality, density, volume.^{9,10}
3. Surgical factors – Achieving primary stability,^{11–13} infection,¹⁴ mechanical and thermal trauma.¹⁵
4. Biomechanical factors – Loading conditions.¹⁶
5. Systemic factors – Systemic diseases,^{17,18} medications,^{19,20}

parafunctional habits.²¹

Amongst all these factors, implant primary stability is one of the most important factor for successful osseointegration.²² There have been many techniques tried in the past to increase the implant primary stability in low density bone. A few among them included bi-cortical fixation,²³ under preparation for the implant bed,²⁴ stepped osteotomy of the implant bed²⁵ and the use of osteotomes and condensers.²⁶ Although demonstrating a considerable amount of success, these techniques did come with drawbacks of their own. Recently, a new technique to increase the density of osteotomy site has been introduced known as osseodensification. Developed by Huwais in 2015²⁷, it makes use of specially designed burs to increase bone density by expansion during osteotomy. The aim of this systematic review was to analyze the quality of published literature on this topic, and assess secondary outcomes such as bone to implant contact (BIC) and the bone area fraction occupancy (BAF). To the best of our knowledge, this is one of the first

* Corresponding author. Irla, Vile Parle West, Mumbai 400056, Maharashtra, India.

E-mail address: ninadpadhye91@gmail.com (N.M. Padhye).

<https://doi.org/10.1016/j.jobcr.2019.10.002>

Received 28 May 2019; Accepted 29 October 2019

Available online 02 November 2019

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systematic reviews on this topic.

2. Materials and method

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.²⁸ The Population, Intervention, Control, Outcome (PICO) question for this review was ‘What is the effect of osseodensification on the primary implant stability for implants placed in humans, on the basis of clinical and histologic evaluation?’.²⁹ A qualitative assessment of the available literature along with advantages, drawbacks and complications of this technique was performed. Two independent reviewers screened titles/abstracts of articles and the full-text of potentially eligible studies.

2.1. Search method and database

A Systematic Search, without language restriction, was performed in PubMed-Medline, Embase and Google Scholar from the year 2010 to November 2018. The following keywords, in various combinations with Boolean operators ‘AND’ and ‘OR’, were selected to search for relevant articles – “osseointegration”, “implant stability”, “implant primary stability”, “osseodensification”, “densah”, “bone density”, “insertion torque” and “removal torque” with no restriction set on document type (Table 1). After selecting the papers, those that were relevant and which fulfilled the inclusion criteria were processed and summarized for relevant data. The references of published articles, reviews, case reports were also hand-searched to include relevant eligible studies. There were no restrictions on the duration of the study.

2.2. Inclusion and exclusion criteria

The inclusion criteria comprised of studies that evaluated the association between implant primary stability, osseodensification and osseointegration. As a secondary finding, the BIC and BAF were also gauged in the studies. Studies were included if they met the following criteria – 1) Randomized controlled trial, cohort, case control or case series/case report. 2) Based on osseodensification principle where specifically designed densifying Densah Bur (Versah, Jackson, MI, USA) were used initially in a clockwise direction during the osteotomy and then in a counter clockwise direction to compact and autograft the bone tissue on the lateral walls and base during the osteotomy. Any study that used methods other than osseodensification to increase implant primary stability were excluded.

2.3. Selection of papers

Studies were assessed on the basis of their title or abstract and those studies which met the inclusion criteria were selected for full text

Fig. 1. Schematic representation of the search protocol used for the selection of studies used in the systematic review.

review. Two authors assessed the studies to be included, and in case of disagreement, the opinion of the third author was sought. The search and selection algorithm is shown in Fig. 1.

2.4. Data collection process

Predefined data collection spread sheets were used for assessment of each publication which consisted of authors’ names, year of publication, sample size, insertion torque value, bone to implant contact, BAF and the duration of the study (Table 2). Study evaluation were done by two authors and confirmed after comparison. The corresponding authors of the respective article were contacted in case of doubt in the extracted data.

2.5. Quality assessment in individual studies

The Animal Research: Reporting In Vivo Experiments (ARRIVE) guidelines comprise of 20 items which are to be considered when animal experiments are to be reported. A modification of the ARRIVE guidelines, specifically designed to assess the quality of experimental implant research, was employed to assess the quality of the studies.^{30,31}

Table 1
Systematic search strategy.

Focus question	What is the effect of osseodensification on the primary implant stability for implants placed in humans, on the basis of clinical and histologic evaluation?
Search strategy	
Population	Missing teeth in low density bone
Intervention	Use of Densah drills for implant osteotomy
Comparison	Osseodensification versus conventional drilling protocol
Outcome	Increased insertion torque value in osseodensification group
Search combination	“osseointegration” OR “implant stability” OR “implant primary stability” OR “osseodensification” OR “densah” OR “bone density” OR “insertion torque” OR “removal torque” OR (“osseodensification” AND “implant stability” OR “implant primary stability” OR “densah”)
Database search	
Electronic	PubMed-Medline, Embase and Google Scholar
Selection criteria	
Inclusion criteria	Randomized controlled trial, cohort, case control or case series/case report. Use of osseodensification drilling protocol.
Exclusion criteria	Methods other than osseodensification used to increase implant primary stability.

Table 2
Details of the all articles on the osseodensification technique along with the insertion torque levels (Ncm), bone to implant contact (%) and bone area fraction occupancy (%).

Sr. No.	Study Authors & Year of Publication	Sample Size	Insertion Torque value	Bone To Implant Contact	Bone Area Fraction Occupancy	Duration of the Study
1.	Trisi et al., 2016 ⁴⁸	Iliac crest of 2 sheeps, 20 implants (10 implants with osseodensification)	Not measured	49.58% ± 3.19% for test group, 46.19% ± 3.98% for control group.	Not measured	2 months
2.	Lahens et al., 2016 ⁵⁰	Ilium of 5 sheeps, 20 implants (10 implants with osseodensification)	100 Ncm* for test group, 25 Ncm for control group	70%* in test group, 50% in control group	44% in test group, 42% in control group	6 weeks
3.	Huwaïs et al., 2017 ⁵⁶	Porcine tibial plateau bone sample, 48 implants (24 implants with osseodensification)	108 ± 56 Ncm* for 6 mm diameter implant and 49 ± 24 Ncm* for 4.1 mm diameter implant for test group; 50 ± 21 Ncm for 6 mm diameter implant and 25 ± 15 Ncm for 4.1 mm diameter implant for control group	Not measured	Not measured	N/A
4.	Lopez et al., 2017 ⁴⁷	Sheep cervical spine, 48 implants (24 implants with osseodensification)	65 Ncm* for test group, 35 Ncm for control group	58%* in test group, 33% in control group	70%* in test group, 40% in control group	6 weeks
5.	Alifarag et al., 2018 ⁵⁸	Sheep ilium, 48 implants (24 implants with osseodensification)	70 Ncm* for test group, 52 Ncm for control group	48%* in test group, 38% in control group	40%* in test group, 32% in control group	3 weeks
6.	Oliveira et al., 2018 ⁴⁹	Sheep ilium, 40 implants (20 implants with osseodensification)	78 Ncm* for test group, 10 Ncm for control group	32%* in test group, 24% in control group	35% in test group, 32% in control group	6 weeks
7.	Slete et al., 2018 ⁴⁶	Porcine tibia, 18 implants (6 implants with osseodensification)	Not measured	60.3%* in test group, 16.3% in control group	62%* in test group, 54% in control group	N/A
8.	Gaspar et al., 2018 ⁵²	41 subjects, 97 implants with osseodensification (only in maxilla)	≥ 45 Ncm for all implants	Not measured	Not measured	N/A
9.	Neiva et al., 2018 ⁵³	Sheep, 36 implants (12 implants with osseodensification)	91.45 Ncm	25% in test group, 22.5% in control group	29% in test group, 27% in control group	6 weeks
10.	Neiva et al., 2018 ⁵⁶	28 subjects, 21 implants with osseodensification (Group 1), 21 implants with osseodensification combined with bone graft (Group 2)	Group 1–36.4 Ncm Group 2–39.1 Ncm	Not measured	Not measured	6 and 12 months
11.	Johnson et al., 2014 ⁵¹ (Case series)	77 subjects, 120 implants with osseodensification	69.28 Ncm* for test group, 29.33 Ncm for control group	Not measured	Not measured	6 weeks
12.	Machado et al., 2018 ⁶⁰ (Case report)	1 subject, 1 implant with osseodensification (extraction and immediate placement)	45 Ncm	Not measure	Not measured	N/A

* Statistically significant.

3. Results

3.1. Study characteristics and outcomes

Fig. 1 shows the search protocol algorithm. With the initial search strategy, a total of 132 potentially relevant articles were found using the combination of the various key words. Study titles and abstracts were screened to weed out the duplicate and irrelevant articles. After the initial screening, 113 articles were rejected on the basis of their title and/or abstract and 19 articles were selected for further analysis. After full text assessment, 7 articles were excluded; 1 study where osseodensification was carried out without the use of Densah burs, 1 article which did not describe the methodology and results, 2 articles that did not measure the insertion torque value or BIC or BAF, 2 literature reviews without complete documentation of cases, and 1 which could not be made available in English.

Thus, a total of 12 articles were included in this review. 8 were animal histological studies, 2 were human based clinical studies, 1 was a case series and 1 was a case report. Amongst them, 8 studies, 1 case series and 1 case report measured the primary insertion torque value whereas 7 studies measured the BIC and 6 studies assessed the BAF.

An increase in the insertion torque value was noted in the osseodensification drilling protocol group (Test group) as compared to the conventional drilling protocol group (Control group) in all the articles assessed. The BIC and BAF were also relatively higher in the test group.

Quality assessment in individual studies was done using modified ARRIVE guidelines in 8 animal studies (Table 3). Out of these, 3 studies had a total score of 20, 3 studies had a total score of 18, 1 study had a total score of 17 and 1 study had a score of 15. The remaining articles were human based studies and were ineligible for a quality assessment.

4. Discussion

4.1. Association between bone density and primary stability

The success of a dental implant procedure is influenced considerably by the quality and quantity of the available bone. Higher rates of implant failure have been noted in implants placed in poor bone density.^{32,33} This is primarily because of the lower primary stability noted in the implants placed in low bone density.³⁴ Decreased primary stability may eventually result in impaired secondary stability, that is, osseointegration.³⁵

The implant primary stability is the direct result of the insertion torque of the implant. An insertion torque of ≥ 25 Ncm is sufficient for a successful implant placement.³⁶ However, in case of immediate loading of an implant, an insertion torque of at least 32 Ncm is required which may escalate to 45 Ncm in areas of relatively lower bone density. Thus, in areas of relatively lesser bone density, osseous densification of the osteotomy site would greatly benefit and improve the long term implant success.³⁷

4.2. Ways to increase implant primary stability

Bone density classification according to Lekholm and Zarb (1985),³⁸ categorized 4 bone quality types based on the morphology and distribution of cortical and trabecular bone. Accordingly, poor density bone (D3-D4) is usually noted in the maxillary posterior regions. Due to the low density of available bone, insertion torque values of the implant placed is usually below the acceptable values. This results in a low success rates for implants placed in these sites.³⁹

Numerous innovative techniques have been employed to enhance the primary stability of an implant. Bi-cortical fixation was shown to significantly increase the implant primary stability.⁴⁰ However, due to increased stress and bending forces, the fracture rate of such implants was significantly higher.²³ Underpreparation of the osteotomy site was another surgical technique for enhancing the implant insertion

Table 3

A quality analysis of the animal studies according to the modified ARRIVE guidelines for assessing quality in implant research (Vignoletti and Abrahamsson, 2012). Scores were assessed for each point and a total score was calculated.

Sr. No.	Score Range	Item Name	Trisi et al. 2016 ⁴⁸	Lahens et al. 2016 ⁵⁰	Huwais et al. 2017 ⁵⁶	Lopez et al. 2017 ⁴⁷	Alifarag et al. 2018 ⁵⁸	Oliveira et al. 2018 ⁴⁹	Slete et al. 2018 ⁴⁶	Neiva et al., 2018 ⁵³
1.	0–2	Title	1	1	1	1	1	1	1	1
2.	0–2	Abstract	1	1	2	1	1	1	1	1
3.	0–2	Introduction and Background	1	1	1	1	1	1	1	1
4.	0–1	Objectives	1	1	1	1	1	1	1	1
5.	0–1	Methods Ethical Statement	1	1	0	1	1	1	1	1
6a.	0–1	Study Design	1	1	1	1	1	1	1	1
6b.	0–1		0	1	0	0	1	1	0	0
7a.	0–1	Experimental Procedures	1	1	1	1	1	1	1	1
7b.	0–1		1	1	1	1	1	1	1	1
7c.	0–1		1	1	1	1	1	1	1	1
8.	0–1	Experimental Animals/Subjects	1	1	1	1	1	1	1	1
9.	0–1	Housing and Husbandry/Dental History	0	0	0	0	0	0	0	0
10a.	0–1	Sample Size	1	1	1	1	1	1	1	1
10b.	0–1		0	0	0	0	0	0	0	0
11.	0–1	Experimental Outcomes	1	1	1	1	1	1	1	1
12a.	0–1	Statistical Methods	1	1	1	1	1	1	0	0
12b.	0–1		1	1	0	1	0	0	1	0
12c.	0–1		0	0	0	0	0	0	0	0
13.	0–1	Results, Numbers analysed	1	1	1	1	1	1	1	1
14.	0–1	Outcomes and Estimation	1	1	1	1	1	1	1	1
15.	0–1	Adverse Effects	1	1	0	1	1	0	0	0
16.	0–2	Discussion/Interpretation	1	1	1	1	1	1	1	0
17.	0–1	Generalizability/Translation	1	0	0	1	0	0	1	1
18.	0–1	Funding	1	1	1	1	0	1	1	0
	0–28	Total Score	20	20	17	20	18	18	18	15

torque.⁴¹ The diameter of the final drill used in the osteotomy is kept smaller than the diameter of the implant to be inserted by about 10%. However, it was suggested, by an in-vitro study, that the healing chamber between the bone and the implant body is lost, which would decrease the speed of woven bone formation, and thus, osseointegration.²⁴

Summers in 1994 introduced the concept of using osteotomes to enhance the density of the prepared osteotomy sites.²⁶ Specially designed condensers and expanders were employed for condensation of low density bone. However, this technique came with its drawbacks. It was assumed that the bone is condensed apically and laterally by using the osteotomes. However, it was noted by a histologic study, that increase in the bone density was only noted in the periapical area, while there was no significant change at the lateral walls.⁴² Repeated impacting of a mallet was required, which is a traumatic technique that may be difficult for the operating surgeon to control, and may result in unintentional displacement, fracture or vertigo.⁴³ The traumatic condensation technique also may cause trabecular micro-fractures, which generally prolongs the healing period due to bone resorption, thus delaying the osseointegration.⁴⁴

4.3. Osseodensification

Due to the shortcomings in the earlier methods of increasing implant primary stability, a new technique termed as osseodensification was developed by Huwais in 2015.²⁷ It is carried out using specially designed drill bits (Densah burs) which combine the advantages of osteotomes along with provision of tactile control during the expansion.⁴⁵ They have 4 or more lands with a negative rake angle making the edges of the bur non cutting and thus, smoothly compact the bone. These drills have a cutting chisel edge and a tapered shank. They thus can enter deeper into the osteotomy site while, the progressive increasing diameter of the drill helps in gradual expansion of the site. In a clockwise rotation (Cutting mode), the drills are used to enter into the bone till the desired depth of the osteotomy.⁴⁶ Following that, counterclockwise rotations (Densifying mode) cause a strong and dense layer of bone tissue to be formed along the walls and base of the osteotomy. This technique burnishes bone along the inner layer of the osteotomy site through controlled deformation.⁴⁷ The purpose is to create a condensed layer of autografted bone along the periphery and apex of the implant. This would, in turn, increase the bone-implant contact enhancing the insertion torque values, and thus, implant primary stability.^{48–53}

The osteogenic parameters around the surface of the implants are quantified by measuring the BIC and the bone growth within the implant threads as a percentage, that is, BAF.^{54–56} A higher degree of osseointegration may be expected in sites with greater BIC and BAF due to the osteoblasts nucleating on instrumented bone that is in close proximity with the implant.^{3,57} Since a layer of autografted bone is present around the implants in an osseodensified site, the close intimacy allows a faster rate of osseointegration.⁵⁸ However, these are histologic measures of the structural connection between bone and implant and do not provide a direct measure of the functionality of that connection.

When this novel concept was introduced, it was claimed that osseodensification method increased the insertion torque from 25 Ncm for implants placed using the standard drilling technique to 49 Ncm in low density bone.⁵⁹ As a secondary finding, it was noted that if the osseodensified osteotomy site remained empty, there was a 91% reduction in its diameter.⁵⁹ This was attributed to the viscoelastic nature of the bone and it was inferred that the viscoelasticity causes a spring-back effect of the bone creating compressive forces against the implant. Osseodensification may thus be particularly useful during implant insertions in the maxillary arches due to the relatively high amount of cancellous bone present. It might however be needed to be used with caution in primarily corticated or denser bone like the mandibular anterior region

due to limited published data for these sites. Also, the drills used for osseodensification have found to increase the temperature and might result in necrosis of the neighboring osteoblasts if not used along with copious irrigation.⁵⁹

5. Conclusions

Even though a modest number of research studies are available, current literature evidence points towards an overall increase in implant insertion torque value, and hence, implant primary stability through the use of osseodensification drilling protocol. The present histologic evidence indicates an increase in BIC and BAF after osseodensification in animal studies. Bone expansion in the osteotomy site is also claimed to be attained using this technique. However, well-designed prospective cohorts and randomized controlled trials are required to fully establish the biologic plausibility and clinical success of this technique in the clinical setting.

Declaration of competing interest

None.

Acknowledgement

Nil.

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