



RESEARCH ARTICLE

The effect of osseodensification and different thread designs on the dental implant primary stability [version 1; peer review: 2 approved, 1 approved with reservations]

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Abstract

Background: It is difficult to achieve good primary stability of dental implants in soft bone, such as that in the posterior maxillae. Osseodensification (OD) burs, working in a non-subtractive fashion, condense the implant osteotomy bone in lateral direction and increase in the bone implant contact. Also, dental implants with deeper threads, and decreased thread pitch can increase initial bone implant anchorage.

Methods: This study utilized 48 custom-made machined surface dental implants that were 13 mm long, with a major diameter of 4.5 mm and a minor diameter of 3.5 mm, a thread pitch of 1 mm, a thread depth of 0.5 mm, and a 4 mm long cutting flute at the apex. The implants were divided into 4 groups, each group was made of 12 implants with a different thread design; V-shaped, trapezoid, buttress, and reverse buttress. The implants were inserted in 4-mm thick cancellous bone slices obtained from the head of Cow femur bone. The osteotomies were prepared by conventional drilling and by OD drilling. Each inserted implant was then tested for primary stability using the Periotest. The Periotest values (PTVs) for the implant stability were tabulated and analyzed using a chi square test at significance level $p < 0.05$.

Results: The results of this study revealed no statistically significant difference between the Periotest readings for the implants in each category placed in either the OD or the regular osteotomies. However, it has been found that the implants placed in regular drilling osteotomies had a significantly better primary stability than the implants placed in OD osteotomies.

Conclusions: It was concluded that OD is not necessary in situations where there is bone of good quality and quantity.

Keywords

Implant primary stability, osseodensification, implant thread designs, Periotest.

Open Peer Review

Referee Status: ? ✓ ✓

	Invited Referees		
	1	2	3
version 1	?	✓	✓
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05 Dec 2018			

- 1 **Khalid Almas**, Imam Abdulrahman Bin Faisal University, Saudi Arabia
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- 3 **Zachary Evans**, Medical University of South Carolina, USA

Any reports and responses or comments on the article can be found at the end of the article.

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Introduction

The primary stability of dental implants depends on the quantity and quality of the available bone, the implant macro- and micro-design, the implant surface features, and the surgical technique used for creating the osteotomy. Conventionally, osteotomies are created with bone-removing drills, and the last drill had a smaller diameter than that of the implant to ensure primary stability. However, this technique is only effective up to certain limits in soft bone, such as that in the posterior maxillae¹.

Osseodensification (OD) burs, working in a non-subtractive fashion, condense the implant osteotomy soft bone in lateral direction, leading to a greater bone volume and density, an increase in the bone implant contact, with subsequent increase in insertion torque levels, and reduction in micromotion²⁻⁶. However, it has been claimed that OD increases the implant bone bed density, but does not improve implant primary stability⁷.

Another maneuver to increase implant primary stability in a poor bone quality situation, is to use an implant with deeper threads, and decreased thread pitch, to increase initial bone implant anchorage. This principle can be applied to different dental implant thread designs; V-shaped, buttress, reverse-buttress, and trapezoid. However, each thread design is thought to give a varying degree of apical and lateral compression to the surrounding bone, which will produce a certain amount of osteocompression and primary stability⁸⁻¹³.

Clinically, the dental implant primary stability can be evaluated using several techniques, such as the amount of torque needed during insertion, or after insertion using the resonance frequency analysis technology implemented in the Osstell device, or the mechanical percussion principle used in the Periotest¹⁴⁻²⁰.

Although the OD may minimize the use of other more invasive techniques, such as ridge splitting²¹, sinus lifting²², and onlay bone grafting²³, there has been a claim that the OD surgical technique may not be effective in improving the primary stability of dental implants⁷, and that the dental implant macro-design is not crucial for the implant primary stability so long as the surrounding bone is of good quantity and quality²⁴. The aim of this study was to test the effect of both variables, the OD surgical technique and the implant macro-design, on the dental implant primary stability, using custom made dental implants with four different thread shapes, with the same thread pitch and depth, placed in two different types of osteotomies prepared by the conventional and the OD technique, and evaluated using the Periotest.

Methods

Implants

This study utilized 48 custom made machined surface dental implants that were 13 mm long, with a major diameter of 4.5 mm and a minor diameter of 3.5 mm. The implants were divided into four groups, each group made up of 12 implants with a different thread design: V-shaped, trapezoid, buttress, and

reverse buttress (Figure 1). All the groups had the same thread pitch of 1 mm, a thread depth of 0.5 mm, and a 4 mm long cutting flute at the apex of the implants.

Bone source and drilling

The head of a Cow femur was used as the bone model²⁵, to reveal its cancellous bone core, it was sliced in 4 cm thick slices in which the implants were inserted. As shown in Figure 2, all the implants were inserted into osteotomies prepared by drills coupled to hydrated hand piece of a dental drill unit (Osseoset 200, Nobel Biocare) to a full length of 13 mm. In total, six implants of each group were inserted into osteotomies prepared by conventional cutting drills (cutting mode, clockwise rotation 1100 RPM), starting with drill size 1.5 mm, 2 mm, 2.4–2.8 mm, 2.8–3.3mm, 3.2–3.6mm and 3.8–4.2mm. The other six were inserted into osteotomies prepared by OD burs (Densah Burs) (OD mode, contra-clockwise rotation 1100 RPM), that started first with conventional drilling with 1.5 mm and 2 mm cutting drills (cutting mode), then OD burs (Figure 3) of size 2.5 mm (DENSAH Bur-G2 VS2228), 3.0 mm (DENSAH Bur-G2 VT2535), and 3.5 mm (DENSAH Bur-G2 VS3238) were used.



Figure 1. The custom-made dental implants used in this study. The thread shapes, from left to right, are V-shaped, buttress, reverse buttress, and trapezoid.

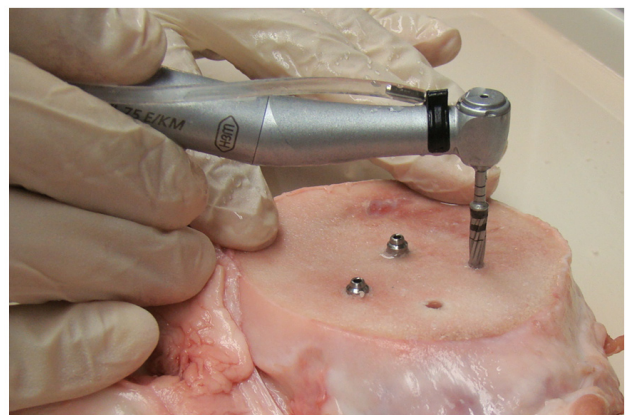


Figure 2. Drilling the osseodensification osteotomy using the densah bur after placing the first implant in regular drilling osteotomy.

Stability testing

Each inserted implant was tested for primary stability using the Periotest, with the tip of the Periotest retractable pin was applied to the same position in the implant abutment (Figure 4). The Periotest values interpretation, as described by the manufacturer, state that values between -8 and zero indicate good primary stability, and values above that range indicate insufficient integration between the implant and the surrounding bone.

Statistical analysis

The Periotest values (PTVs) for the implant stability were tabulated and analyzed using statistical package for social science

(SPSS version 20 for windows). Comparisons between the study groups were carried out using the chi square test at significance level $p < 0.05$

Results

Comparison of implant types

This work assessed the effect of OD versus regular drilling on dental implant primary stability. To rule out the effect of the implant design, the most commonly used thread shapes were tested in both osteotomies. The Periotest was used to read each implant primary stability. The results of this study revealed no statistically significant difference between the Periotest readings for the implants in each category placed in either the OD or the regular osteotomies (Table 1).

Comparison of regular and OD osteotomies

When all the implants placed in regular drilling osteotomies were compared to all the implants placed in OD osteotomies, statistical analysis of the Periotest readings for primary stability has shown that the implants placed in regular drilling osteotomies were significantly more stable than the implants placed in OD osteotomies (Table 2).



Figure 3. The osseodensification Densah burs.



Figure 4. Using the Periotest to evaluate the dental implant primary stability, the Periotest tip is applied to the abutment.

Table 1. Comparison of the Periotest values for primary stability of the different implant threads placed in osseodensification (OD) and regular osteotomies.

Thread design	Drilling method	Periotest values for each implant insertion						Mean	SD	P
		First	Second	Third	Fourth	Fifth	Sixth			
V-shaped	Regular	-7	-4.1	-5.5	-7.5	-7.4	-6.9	-6.4	1.33	0.512
	OD	-8	-7.6	-6.1	-6.2	-6.2	-6.9	-6.8	0.81	
Trapezoid	Regular	-5.1	-6.5	-7.8	-7.7	-7.5	-6.9	-6.9	1.02	0.076
	OD	-7.2	-6.8	-5.3	-4.4	-5.1	-4.6	-5.6	1.16	
Buttress	Regular	-7.7	-6.6	-8	-8	-7.7	-7.7	-7.6	0.51	0.06
	OD	-8	-6.9	-5.9	-5.8	-5.3	-7.8	-6.6	1.12	
Reverse-buttress	Regular	-7.3	-6.3	-7.2	-7.1	-7.4	-7.2	-7.1	0.39	0.121
	OD	-8	-7.2	-6	-5.6	-5.8	-4.9	-6.3	1.13	

Table 2. Comparison of the Periotest values for primary stability of the all the implant placed in osseodensification (OD) versus those placed in regular osteotomies.

Drilling method	Mean	Std. deviation	n	P value
Regular	-7.00	0.95	24	0.026
OD	-6.31	1.11	24	

Discussion

The aim of this study was to evaluate the effect of dental implant osteotomy preparation, using the OD technique, on the dental implant primary stability compared to conventional drilling. Since the dental implants may present many variables, such as the thread designs and surface treatments, which may affect the primary stability, this study utilized custom-made implants, with machined surface to avoid the effect of surface treatments on primary stability, and different thread patterns having the same thread pitch and depth, to detect which thread design will provide better primary stability in conjunction with OD.

Since the implants used in this study were custom-made, it was difficult to use the resonance frequency analysis to evaluate the primary stability of the implants as the Osstell device requires the use of a smart peg which was difficult to custom make; however, the Periotest was used. Javed *et al.*¹⁴ have stated that the both the Osstell and the Periotest can be used to measure the dental implant primary stability, although the Periotest readings are less sensitive. Andresen *et al.*¹⁶ have also approved the use of Periotest once the clinicians consider its limitations and the difficulty in results interpretation. A different perspective was given by Noguero *et al.*¹⁷ who stated that the Periotest mechanical testing would definitely give a better evaluation for implant stability than any radiographic study. Furthermore, Oh *et al.*^{18,19} found that the Periotest was comparable and as reliable as the Osstell. However, Aparicio *et al.*²⁰ emphasized that it is important to consider several readings of either device over a long period of time in order to be able to evaluate the implant stability.

In the presence of soft bone, under-sizing the implant osteotomy is thought to give a better implant primary stability; however, Jimbo *et al.*¹ stated that this technique is efficient when the implant bed is decreased by 10% of its diameter and that any further decrease did not improve the primary stability. Huwais and Meyer² introduced the bone compaction technique through the OD drilling, and claimed that it increased the insertion torque, bone-to-implant contact, and accordingly resulted in greater primary stability compared to conventional drilling and to Summers¹⁵ osteotome technique. This hypothesis has been confirmed by the work of Lahens *et al.*³ who reported a significantly higher bone-to-implant contact for OD, and Lopez *et al.*⁴ who tested the OD technique *in vivo* and reported its significant success over conventional drilling mechanically using the pull-out testing and microscopically using the histomorphometry.

Additionally, Trisi *et al.*⁵ have shown that OD allows the use of wider implants diameters in narrow edentulous ridges, with consequent increase in bone volume. This increase in bone was later shown to reach 30% of the original ridge dimensions by Podaropoulos⁶.

However, the results of this study did not find any statistically significant difference between the effects of OD and conventional drilling on the dental implant primary stability with any of the different thread designs used. This came in agreement with the findings of Wang *et al.*⁷, who reported that OD increased the apparent density of the peri-implant bone, but did not significantly improve the bone-implant contact, or the primary stability, and that OD created high strains at the bone implant interface, with damage to the bone trabeculae leading to extended periods of resorption and delayed secondary stability.

In accordance with the findings of Abuhussein *et al.*⁸, the implants used in this study had deep threads with a decreased thread pitch to ensure bone anchorage, and based on the conclusion of Chong *et al.*¹¹, being without self-tapping properties, the threads were thought to provide higher primary stability than self-tapping threads. However, none of the tested thread shapes has shown any superiority in achieving better primary stability.

Notably, the results of this study showed that there was no statistically significant difference between the OD and the regular drilling techniques, nor between the different thread designs used based on the Periotest values recorded for the implant primary stability. Considering the bone model used, Alkhodary *et al.*²⁵ have stated that the elastic modulus of the cancellous bone of the cow femur head was comparable to that of the cancellous bone of the human mandible, which is in turn more compact than the bone in the posterior maxillae, and according to Chong *et al.*¹¹ and Summers¹⁵, optimal bone quality and quantity can mask any difference in the implant different designs. This suggestion has been further potentiated by Bischof *et al.*²⁴ who studied the factors affecting the dental implants primary stability, and reported that it is not the diameter or length of the implant, nor the implant thread deepening that affect primary stability, rather than the bone type in the mandible or the maxilla.

Accordingly, it can be concluded that OD is not useful in compact bone, and might have a different effect in soft bone, and that the effects of different thread designs are more noticed in cancellous, rather than compact bone as shown by Kong *et al.*¹⁰ who reported different stress distribution patterns by the different thread shapes at the cancellous bone-implant interface. This came in agreement with the second finding of this study, where all implants placed in regular osteotomies had a significantly better primary stability than all the implants placed in OD osteotomies. This can be explained by the fact that soft bone has wider marrow spaces between the bone trabeculae, allowing for bone compaction, rather than the compact bone which the OD would lead to lateral compression that exceeds the viscoelastic limit of the thick and dense bone trabeculae, with subsequent damage and a weaker bone implant interface. Also, it is recommended to examine the effect of OD in an *in vivo*

situation, where the bone available is soft, and where the monitoring process by the Periotest, or the resonance frequency analysis can be conducted several times to detect the effect of OD on both the primary and secondary stability of the dental implants.

Data availability

All data underlying the results are available as part of the article and no additional source data are required.

Grant information

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The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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Open Peer Review

Current Referee Status:



Version 1

Referee Report 14 May 2019

<https://doi.org/10.5256/f1000research.18905.r47949>



Zachary Evans

Department of Stomatology, College of Dental Medicine, Medical University of South Carolina, Charleston, SC, USA

This is a focused manuscript attempting to evaluate the effects of thread design on implant stability with an OD drill protocol in trabecular bone. It is a surprise that the OD protocol did not improve initial implant stability. Therefore, this is clinically relevant as it may influence providers to use the OD protocol for ridge expansion or sinus lifting, but not for densification. Studies like this are giving us information that may influence our clinical decisions in this regard. It is a simple, but very useful study that I hope will lead to a larger clinical study.

Two small comments to consider:

1. Consider the use of the animal model terminology "bovine" vs. "Cow".
2. Consider adding a comment on clinical relevance to the discussion - for example, what clinical scenarios would be appropriate or not for the OD protocol.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Implant surface technology, digital strategies for implant planning

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Referee Report 29 March 2019

<https://doi.org/10.5256/f1000research.18905.r45551>



Jun Lee

Department of Oral and Maxillofacial Surgery, School of Dentistry, College of Dentistry, Wonkwang University, Iksan, South Korea

This paper appears to be a comparison of densah bur and conventional drill system according to implant design in animal models. Overall, the content is simple but well proven. Only in this experiment, it is considered that the animal model is designed properly.

I mention a few minor revisions:

1. Abstract is 4-mm thick cancellous bone slices, but it is written as 4-cm in the text.
2. In the experimental design, four implants are placed in one Cow femur slice, and I wonder how much distance there is between the implants (critical distance between implants). Indeed, the important consequences of this experiment would be to provide an experimental condition that does not interfere with drilling or implant placement to yield reliable results

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: This paper appears to be a comparison of densah bur and conventional drill system according to implant design in animal models. Overall, the content is simple but well proven. Only in this experiment, it is considered that the animal model is designed properly

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Referee Report 23 January 2019

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Khalid Almas

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This is an interesting in vitro study. Osseodensification technique is getting popularity due to improved local bone quality for implant placement with the technique.

The pilot work is interesting as far as the unified approach is concerned with 13 mm long implants and customized surface configurations. It is suggested that in future following variations should be considered to test the effect of osseodensification.

1. Implants length less than 13 mm (8-11 mm)
2. Variable width.
3. Different thread pitch and depth.
4. Implant surface characteristics should be with SLA surface or any other non-machined surface.
5. The immediate stability of implants may not reflect the normal healing and stability physical equilibrium. As in real time clinical implant surgery, the initial stability and after 1-2 weeks stability may vary.

The discussion part of the manuscript should include variables mentioned above and future studies may include those points.

Further, radiographic or any other imaging technique should be used to see immediate bone-implant contact in both regular and OD technique.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Periodontics and implant Dentistry

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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