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Original Article

Do increased drilling speed and depth affect bone viability at implant site?

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ABSTRACT

Background: The aim of this study was to assess the effect of increasing the drilling speed and depth during implant site preparation on bone viability.

Materials and Methods: In this prospective cohort study, participants were divided into four groups based on the speed and depth of drilling at the first molar site in the mandible. Participants underwent drilling at Group 1: 1000 rpm and 10 mm depth, Group 2: 1500 rpm and 10 mm, Group 3: 1000 rpm and 13 mm, and Group 4: 1500 rpm and 13 mm. Obtained specimens were assessed histologically to the qualitative measurement of bone viability, and the percentage of vital bone were evaluated by histomorphometric analysis. ANOVA was used to compare age and the mean percentage of vital bone and Tukey's test as *post hoc* was applied for pairwise comparison of groups.

Results: A total of 100 participants were studied in four groups (25 subjects in each group). Histological evaluation revealed a low level of bone viability maintenance in all groups. Histomorphometric analysis showed the mean percentage of vital bone was 9.5 ± 3.91% in Group 1, 8.86 ± 3.84% in Group 2, 8.32 ± 3.80% in Group 3, and 4.27 ± 3.22% in Group 4. A significant difference was noted in the mean percentage of bone viability among the four groups ($P = 0.001$).

Conclusion: It seems that increasing the drilling speed or depth during dental implant site preparation does not affect the mean percentage of cell viability, while the increase in both depth and speed may decrease the percentage of viable cells.

Key Words: Bone, vitality, dental implant, drilling

INTRODUCTION

Dental implants are placed into holes prepared by rotary drills or burs.[1] The use of drills and burs may be associated with bone necrosis due to mechanical and thermal damage.[2] The process of rotary osteotomy results in overheating, which is due to friction and subsequent heat transmission to the bone.[3] Overheating during implant site preparation has a negative effect on the osteointegration process and the final outcome of implant rehabilitation.[4]

Several factors are effective in the overheating process such as bone density, irrigation system, drill cutting efficiency, and increasing the depth and speed of drilling.[1] Atraumatic surgical preparation seems to be essential for successful healing and consists of several conditions, including avoidance of overheating

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during the preparation of the osteotomy.[5] *In vivo* studies have demonstrated the adverse effects of heat production and its interference with the process of bone healing; the critical temperature in bone healing which would not lead to necrosis has been identified.[6] Independent increase in either the speed or the load results in temperature increase in bone. Increasing both the speed and the load has provided more efficient cutting without any significant increase in temperature.[7] There is a lack of evidence regarding bone viability histomorphometrically in various depths and speeds of drilling during implant site preparation in humans. Most of these studies focused on autogenous bone grafts which harvested during implant site preparation.[8-10] However, bone vitality within these specimens was a controversial issue that encompasses a wide range between proper preserved osteocytes and osteoblasts which maintain bone tissue[9] to 100% loss of bone vitality and through the absence of osteocytes.[10] The purpose of this study was to assess the effect of increased drilling speed and depth on bone viability during the preparation of implant sites.

MATERIALS AND METHODS

The authors designed a prospective cohort study and patients introduced to oral surgery clinics between September 01, 2014, and March 31, 2015, were assessed. The study was approved by the committee of medical ethics group of Shiraz University of Medical Sciences. Individuals eligible for inclusion in the study needed a dental implant in the mandible at the first molar site. The first molar had been extracted at least 1 year before implant placement. Participants were excluded from the study if they needed a bone graft during implant placement or tooth extraction. All participants attained a cone-beam computed tomography (CBCT, Quantitative Radiology SRL Co., Verona, Italy) scan for evaluation of bone quantity before surgery.

Surgical approach

First, a full thickness mucoperiosteal flap was made on the ridge at the first mandibular molar site and reflected to access the underlying bone. IBS implant magic drilling system (H1D 38 and H1D 43, InnoBioSurg Co., Ltd., South Korea) was used in all subjects [Figure 1]. The drills have a groove in the middle to accommodate removed bone core. Drilling was performed according to the manufacturer's instructions. During drilling procedure bone particulates were collected gradually. In addition, after drilling, bone sample accumulated in the groove when the drilling was done. All harvesteed specimens were sent for histological examinations. All surgeries were performed by a single calibrated oral and maxillofacial surgeon with a trained assistant. In this study, the external irrigation was administered with the same pressure as a surgical motor (NSK, Japan).

Figure 1: IBS implant system: a kind of drill.

Participants were divided into four groups based on the speed and depth of drilling. All drilling speeds were in the standard range which declared by previous investigations.[11-13] Subjects underwent drilling at 1000 rpm speed with 10 mm depth in Group 1, 1500 rpm with 10 mm depth in Group 2, 1000 rpm with 13 mm depth in Group 3, and 1500 rpm with 13 mm depth in Group 4.

Histological and histomorphometric analysis

Samples were fixed in formalin solution, decalcified in 5% nitric acid for 24 h, serially sectioned by a microtome (Leica RM2125RT Microtome®, Leica, IL, USA) and stained with hematoxylin and eosin (Sigma-Aldrich, St. Louis, USA).

One calibrated examiner determined necrotic bone trabeculae, trabeculae without any osteocytes in lacunas, without any osteoblasts at rims, and ragged borders elements by light microscopy (Olympus, SZX 9, Tokyo, Japan) and its DP72 camera at ×200 magnification. The 5 mm sections analyzed by quantitative histomorphographic assessment of stained slides by a PC-based image analysis system (Image-Pro Plust, Media Cybernetic, Silver Spring, MD, USA) to evaluate the mean percentage of bone vitality in each specimen.[10]

Statistical analysis

The statistical analyses were performed using the statistical package SPSS for PCs, version 19 (Microsoft, IL, USA). ANOVA was used to compare age and the mean percentage of vital bone. *Post hoc* Tukey's test was applied for pairwise comparison of the groups. Chi-square test was used to compare gender among the groups.

RESULTS

A total of 100 subjects were studied in four groups (25 individuals in each group). The mean age was 38 ± 9.32 years. There was no difference among the four groups regarding age (P = 0.89). Data analysis did not demonstrate any difference in gender among the groups (P = 0.98) [Table 1]. Histological evaluations of the samples with light microscopy showed bone although the bone structures were well-conserved, in all groups, a few number of osteocytes exists within the calcified matrix, and osteoblastic rim was not preserved well [Figure 2]. Histomorphometric analysis represents the mean percentage of bone viability was 9.5% ±3.91% in Group 1, 8.86% ±3.84% in Group 2, 8.32% ±3.80% in Group 3, and 4.27% ±3.22% in Group 4. The results showed a significant difference in the mean percentage of bone vitality among the four groups (P = 0.001) [Table 2].

Tukey's test as *post hoc* demonstrated significant differences between Groups 4 and 1, Groups 4 and 2, and Groups 4 and 3 (P = 0.001) [Table 3].

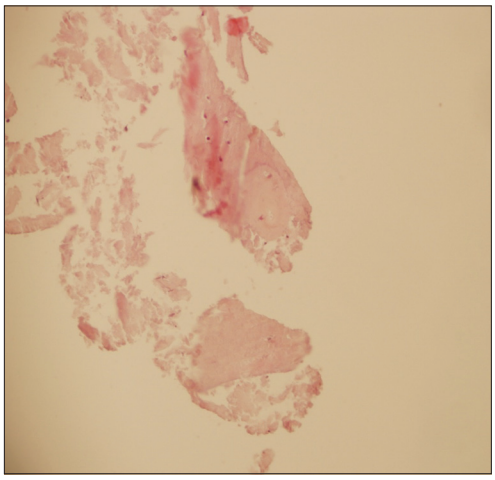

Figure 2: Obtained bone chips show necrosis and a few scattered vital trabeculae (H and E staining, ×200).

DISCUSSION

Changes in intrabony temperature caused by frictional heat generated by drilling can lead to bone necrosis. Increased drilling speed and depth are important factors in heat production during implant site preparation.[5] Several methods have been used to measure the temperature during implant site preparation.[14,15] Most previous studies have measured temperature changes by a thermocouple.[16] As bone necrosis is the final result of overheating during drilling, assessment of bone vitality would be an accurate method to evaluate the extent of cell injury due to excessive heat.

Higher drill force and speed may minimize osseous heating by minimizing the time of in-bone drill operation and heat generation.[17] Brismal studied

Table 1: Comparison of variables among the four groups

Variables	Group 1	Group 2	Group 3	Group 4	*P*
Age (years)	39±8.65	38.96±10.47	36.84±11.19	37.2±9.63	0.81*
Gender					
Male	13	13	13	12	0.98**
Female	12	12	12	12	

*ANOVA, **Chi-square test

Table 2: Comparison of bone viability among the four groups

Outcome	Group 1	Group 2	Group 3	Group 4	ANOVA
Percentage of bone vitality	9.5±3.91	8.86±3.84	8.32±3.80	4.27±3.22	0.001

Table 3: Pairwise comparison of groups by the *post hoc* test

Groups	Mean difference	*P*
Group 1		
2	0.6	0.94
3	1.14	0.70
4	5.18	0.001
Group 2		
1	−0.6	0.94
3	0.54	0.70
4	4.9	0.001
Group 3		
1	−1.14	0.70
2	−5.4	0.96
4	4.04	0.001
Group 4		
1	−5.18	0.001
2	−4.9	0.001
3	−4.04	0.001

the effect of speed, pressure, and time on bone temperature during drilling of implant sites. He measured the temperature while drilling bovine cortical bone at speeds of 1800 and 2400 rpm and loads of 1.2 and 2.4 kg. He concluded that increasing both the speed and the load together allowed for more efficient cutting with no significant increase in temperature.[7] Another study demonstrated that drilling at 2500 rpm decreased the risk of osseous damage which may enhance the initial healing of dental implants. The authors suggested that this may decrease the extent of nonvital zone adjacent to an implant after surgery.[5] The results showed that the drilling time proportionally decreased with increased rotation speed, and the temperature dropped considerably within 10 s at high rotation speed. However, it is questionable whether the time was enough to destroy the majority of vital cells.[18]

According to our knowledge, there are a few available studies which investigated bone of human subjects in the implant preparation site.[8-10] In our study, increasing the speed of drilling or depth did not affect the percentage of bone vitality. However, there was a significant deterioration of bone vitality when both speed and depth of drilling increased. Several factors may cause an increase in bone temperature and subsequent thermal osteonecrosis namely the drilling speed, drill feed rate, cooling, drill diameter, drill point angle, drill material and wear, drilling depth, predrilling, drill geometry, and the thickness of cortical bone.[19] In accordance to our results, Berengo *et al*. revealed low vital bone harvested during implant preparation.[10] Although on account of their aim they did not investigate bone for implant therapy, their study showed related findings to our results. In this study, they histomorphometrically evaluated the amount of vital bone with harvested among four different ways encompass round bur on low-speed handpiece (40,000 rpm), bur on high-speed handpiece, spiral implant bur on low-speed handpiece (1000 rpm), safe scraper, rongeur pliers, gouge shaped bone chisel and mectron piezosurgery. They concluded obtained bone with round bur on low-speed and high-speed handpiece, spiral implant bur, and safe scraper is not appropriate for grafting as represented by the absence of osteocytes and the reign of nonvital bone. On the other hand, in contrast to our findings, Santagata *et al*. in 2014 showed the proper amount of vital bone based on the histological evaluation.[8] In this study, they did not conduct histomorphometric analysis, and through qualitative light microscopy assessment, a substantial number of osteocytes and osteoblasts was seen. A feasible explanation for this disparity is that Santagata *et al.* applied a surgical motor (Implantmed, W and H GmbH, Burmoos, Austria) at a speed of 350 rpm and a torque setting of 45 Ncm which was different with our system and procedure. However, for the most accurate evidence-based decision-making more investigation required.

Karaca *et al*. showed maximum temperature rise with an increased drill tip angle and mineral density of bone. The bone quality around the drilling site was found to be worse than the bone samples exposed to low temperatures.[20] Augustin *et al*. studied the influence of different drilling parameters on the increase of bone temperature. They used 2.5, 3.2, and 4.5 mm drill diameters, 188, 462, 1140, and 1820 rpm drill speeds and 24, 56, 84, and 196 mm/min feed rates. Their results showed that a combination of drilling speed and drill diameter with the use of external irrigation was required to maintain temperatures far below the critical point. Rise in temperature above the critical point was recorded when 4.5 mm drill was used at higher speeds (1140 and 1820 rpm).[21] A recent meta-analysis by Möhlhenrich *et al*. demonstrated that the highest and the lowest temperatures were 64.4°C and 28.4°C, respectively, during drilling. They suggested standard variables such as an axial load of 2 kg, drilling speed of 1500 rpm, irrigation, standard artificial bone blocks, and the use of infrared thermography for future studies.[22]

In the current study, the amount of force during drilling was not measured for every case, which was a limitation of our study. Another limitation was a lack of documentation of bone density for each subject. A sampling of the outer wall of a drilling hole may give more reliable histological information about bone condition; however, it was impossible to take such samples from human subjects because it was unethical to manipulate a prepared hole.

It seems, as a conclusion, that increased drilling speed or depth during dental implant site preparation does not affect the mean percentage of bone vitality. However, a significant increase in both depth and speed of drilling may result in a reduction of vital bone percentage.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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