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Original research

A comparative study to evaluate the heat generated during osteotomy with conventional drill, trephine and alveolar expander

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Purpose
Excessively produced heat could lead to clinical failure of osseointegration. This study was done to compare the heat generated during osteotomy with the conventional drill, trephine, and alveolar expander .

Materials and Methods
This in vitro study was performed on ten bovine femoral bones. In each femoral bone, three osteotomy sites were prepared at a distance of 1.5cm using the conventional drill, trephine, and alveolar expander. During osteotomy, the site was irrigated with a copius amount of normal saline. Osteotomy sites of 3.6 mm in diameter and 11.5 mm in length were prepared using the conventional drill and bone trephines. The alveolar expander used for preparing the osteotomy site was 3.5mm, the nearest dimensions available. The temperature rise was measured using a thermocouple thermometer. Repeated measures ANOVA and Fisher's least significant difference pairwise comparison test was done for statistical analysis.

Results
Repeated measures ANOVA revealed a significant difference in the heat generation with the conventional drill, trephine, and alveolar expander ($p<0.001$). The mean heat generated was maximum with the trephine (28.26±0.246 ºC) followed by the conventional drill (27.27±0.297 ºC) and least with alveolar expander (25.64±0.142 ºC). Pairwise comparison showed a significant difference in heat generated during osteotomy with conventional drill compared to trephine ($P=0.023$), conventional drill compared to alveolar expander ($P=0.014$), and trephine compared to alveolar expander ($P< 0.001$).

Conclusion
The heat generated with trephine was maximum compared to the alveolar expander and conventional drills. If in case trephine is to be used, both internal and external irrigation must be used. Less heat generation during osteotomy by alveolar expander seems very promising and advantageous for better osseointegration.

Keywords: *Alveolar expander, dental implant, heat generation, osteotomy, trephine*

Introduction

Implant dentistry has become extremely popularized and emerged as a viable option in the present era. Most clinicians recommend it as the first choice for replacing missing teeth. Literature has well stated that implant success principally depends on the extent of osseointegration. Successful osseointegration is primarily dependent on design, chemical composition, surface texture and shape of implant, medicaments, heat produced during osteotomy, and initial healing response at the implant site (1,2).

A considerable number of research studies have been performed on dental implant design but less has been attempted on implant site-relat-

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ed factors (3). The heat produced during site preparation is one of the vital factors for the lack of osseointegration. The temperature rise is mostly due to friction between the cutting surface of drills and bone. However, the ideal geometric design for a drill to diminish heat generation is still unclear (4,5). Excessively produced heat could lead to clinical failure of osseointegration. Additionally, this frictional heat could lead to a certain degree of necrosis of cells. The temperature threshold for tissue survival during osteotomy is 47 ºC when drilling is done for more than 1 min (6).

While preparing the implant sites with drills, it is essential to keep an eye on heat injury since osseous tissues are highly prone to thermal insult (7). To preserve the bone from rising temperature during drilling, different irrigation systems are utilized. Predominantly, sterile saline solutions are the material of choice for clinicians. Modifications in drill designs are also introduced and experimented with to control heat. Drill systems with internal irrigation are very popular and efficient in this regard (8). The study by Gupta *et al*. (9) evaluated heat generation during osteotomy with the conventional drill and trephine and a study by Bhargava *et al.* (10) evaluated bone loss during osteotomy using the standard drill, bone trephine, and alveolar expanders. Studies evaluating heat generation by alveolar expander seem to be not attempted yet.

Therefore, considering all these imperative factors, this study was conducted to compare the heat generated during osteotomy with the conventional drill, trephine, and alveolar expander in bovine femoral bone. The null hypothesis undertaken was that there was no difference in heat generation during osteotomy with conventional drill, trephine and alveolar expander.

Material and Methods

Study design

This in vitro study was conducted on the fresh bovine femoral bone obtained from the slaughtered goats for human consumption at the local butcher's shop to simulate the clinical conditions. The femoral bones were obtained from healthy male goats, with a mean age of 17.9±0.7 months (range 17.5-19 months) and mean weight of 34.8±0.7 Kg (range 34-36 Kg).

The study was performed on ten bovine femoral bones, slaughtered within 1h of starting the osteotomy. In each femoral bone, 1.5cm was kept as a safe distance between osteotomy sites to standardize the different drilling procedures and to check any possible effects of adjacent osteotomy sites.

Drilling procedures and heat generation

In each femoral bone, three osteotomy sites were prepared at a distance of 1.5cm using an implant drill, trephine, and alveolar expander (Figure 1a-c). Osteotomy sites of 3.6 mm in diameter and 11.5 mm in length was prepared using the conventional implant drill and bone trephines. The alveolar expander used for preparing the osteotomy site was 3.5mm, as it was the nearest dimension available. The temperature rise was measured using a thermocouple thermometer (Figure 2). A horizontal hole at 90-degree angle to the midpoint of the osteotomy site (at a depth of 5.75mm) was made in all the femoral bones for placement of the thermocouple. The thermocouple was placed such that the distance between the sensor tip and the implant site was 0.5mm to record the temperature.

The osteotomy site preparation with implant drills (Surgical Kit, DR0010, DR0020, DRN028-DRN036, ARDS Implants, Tefen,

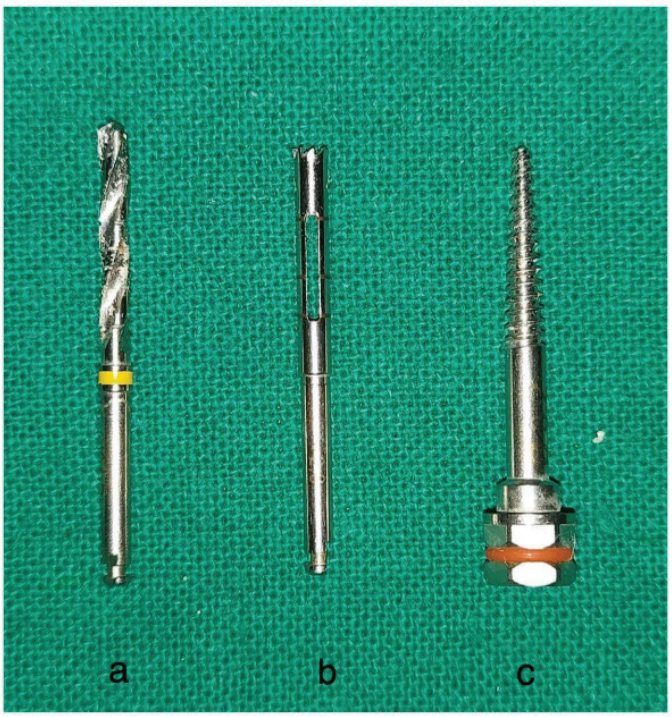

Figure 1. *a) Conventional drill. b) Trephine. c) Alveolar expander.*

Figure 2. *Temperature measurement with thermocouple thermometer.*

Italy) was done in the recommended pattern at 800 rpm with a reduction gear dental implant handpiece (SII 20:1, Daegu, Korea), driven by a surgical motor (MPi 2.0, Madrid, Spain) with profuse irrigation using normal saline. At the first site, a marking was made on the femoral bone with the implant marking drill. The osteotomy was completed in sequence using a 2.0 mm pilot drill, followed by 2.8 mm, 3.2 mm, and 3.5 mm drills to achieve a site of 3.6mm diameter and a depth of 11.5mm. After using the last drill of 3.6 mm, the temperature was measured with the thermocouple thermometer (Divinext -50 ^{0}C to 1300 ^{0}C, Type K, Vani International, Vadodara, India) (Figure 3a). The temperature was measured three times in all the ten femoral bones and the mean temperature was recorded.

The osteotomy site preparation with trephines (PGD Kit, DR0010-DR0036, ARDS Implants, Tefen, Italy) was also done in the recommended pattern at 800 rpm with a reduction gear dental implant handpiece (20:1), driven by a surgical motor with profuse irrigation using normal saline. At the second site also, firstly a marking was made on the femoral bone with the implant marking drill. The osteotomy was done in sequence using a 2.0mm pilot drill, followed by 2.8mm, 3.2mm, and 3.6mm drills to achieve a site of 3.6mm diameter and a depth of 11.5mm. After using the last trephine drill of 3.6mm, the temperature was measured with the thermocouple thermometer (Figure 3b). The temperature was measured three times in all the ten femoral bones and the mean temperature was recorded.

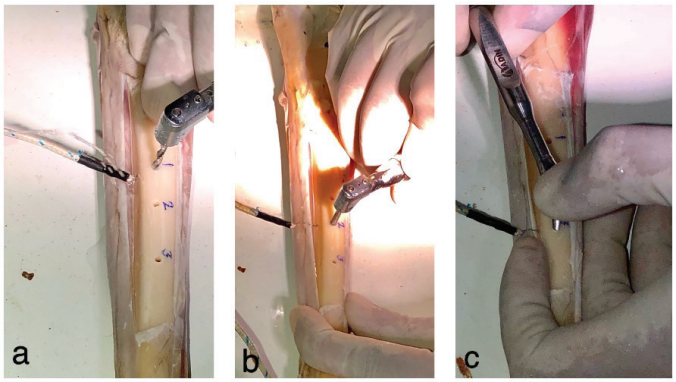

Figure 3. *Osteotomy site preparation in bovine femoral bone. a) with conventional drill. b) with trephine. c) with alveolar expander*

At the third site, the osteotomy was done with the alveolar expander (SBE01-04, IDEA implant system, Chennai, India). During osteotomy, profuse irrigation was ensured with normal saline at this site too. The osteotomy was started with a marking on the femoral bone with flame-shaped dental implant marking bur followed by pilot drilling with a 2.0mm pilot drill. The site was further expanded using a tapered screw-type alveolar expander in the sequence of 3.2mm, 3.4mm and 3.5mm to achieve a site of 3.6mm diameter and a depth of 11.5mm. While using the different diameters of alveolar expander, a break of 10 sec was taken to allow adequate expansion of the bone. After using the last alveolar expander of 3.5mm, the temperature was measured with the thermocouple thermometer (Figure 3c). The temperature was measured three times in all the ten femoral bones and the mean temperature was recorded.

Statistical analysis

The temperature rise was tabulated in an excel sheet. The temperature was measured three times with the drill, trephine and alveolar expander in all the ten femoral bones, and the mean temperature was calculated. The data were analyzed using the Statistical Package for the Social Sciences (version 20.0 version, IBM, Chicago, IL, USA). Repeated measures ANOVA was done to find whether there was a significant difference exist in heat generated during osteotomy with the conventional drill, trephine, and alveolar expander. Fisher's least significant difference pairwise comparison was done to find the significant difference in heat generated during osteotomy between different drilling techniques. *P*-value <0.05 was considered statistically significant.

Results

The descriptive statistics of heat generated during osteotomy with the conventional drill, trephine, and alveolar expander were presented in Table 1. Repeated measures ANOVA for comparison of heat generated during osteotomy with conventional drill, trephine and alveolar expander was presented in Table 2. The mean heat generated was maximum with a trephine (28.26±0.246 ºC) followed by the

Table 1: *Descriptive statistics of heat generated during osteotomy with conventional drill, trephine and alveolar expander*

Group	n	Reading	Mean (^{0}C)	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Conventional drill	10	1	27.03	0.327	26.25	27.81
		2	27.38	0.303	26.60	28.17
		3	27.40	0.316	26.62	28.18
Trephine	10	1	28.18	0.275	28.18	28.18
		2	28.15	0.262	28.15	28.15
		3	28.45	0.275	27.83	29.07
Alveolar expander	10	1	25.54	0.171	25.54	25.54
		2	25.66	0.172	25.66	25.66
		3	25.72	0.193	25.72	25.72

n=number of femoral bones

conventional drill (27.27±0.297 ºC) and least with alveolar expander (25.64±0.142 ºC). When the heat generated with a conventional drill during osteotomy was evaluated, the maximum heat generated value obtained was 28.8 ºC and the minimum was 25.5 ºC. In the case of heat generated with a trephine, the maximum value obtained was 29.2 ºC and the minimum was 27.4 ºC. In the case of heat generated with alveolar expander, the maximum value obtained was 26.0 ºC and the minimum was 25.3 ºC.

The Fisher's least significant difference pairwise comparison was done to find the difference in heat generated during osteotomy with the conventional drill, trephine, and alveolar expander (Table 3). Pairwise comparison showed a significant difference in heat generated during osteotomy with conventional drill compared to trephine (*P*=0.023), conventional drill compared to alveolar expander (*P*=0.014), and trephine compared to alveolar expander (*P<0.001*).

Discussion

The null hypothesis undertaken in this study was rejected, as differences exists in heat generation during osteotomy with the conventional drill, trephine, and alveolar expander. The heat generated was minimum with a alveolar expander (25.64±0.142 ºC) and maximum with trephine (28.26±0.246 ºC).

The implant-supported prostheses should be given following proper guidelines with minimal surgical intervention (11). One of the important requisites during implant placement is proper preparation of the osteotomy site. During osteotomy, care should be taken to avoid excessive temperature rise at the site due to implant drills, so that damage to the surrounding tissues can be prevented. Excess heat generated by implant drills while osteotomy causes necrosis of bone. The increase in temperature and the period of thermal exposure causes an exponential increase in injury to the bone (12,13). During osteotomy, external irrigation with low-temperature saline seems to be quite effective in cooling the bone, so continuous irrigation of the osteotomy site in between the drilling should be done (14). In the present study, also external irrigation with low-temperature saline was done with all the three drilling techniques.

Researchers had proposed incremental preparation of the implant site with a sequence of implant drills in increasing diameter to reduce the heat generation and damage to the bone damage during osteotomy. A graded series of the drill was found to be better than a single large drill for osteotomy site preparation (15-17). A similar concept was followed in the present study also and incremental site preparation with all the three drilling techniques was followed. Gupta *et al.* (9) had done the infrared thermographic evaluation of rise in temperature with conventional drill and trephine and found that temperature rise was significantly higher for trephine (52.98±1.67 °C) than for conventional drills (48.20±0.67 °C) at the tip. In the present study also the heat generated was higher with the trephine (28.26±0.246 °C) compared to conventional drill (27.27±0.297 ºC) and the difference was statistically significant (*P*=0.023). The heat generated with the trephine was maximum due to the fact that trephine has the closely arranged cutting blades at the tip, which generates much friction and localized heat production with uneven distribution of heat. In the case of conventional drills, the blades were present throughout the drill, which does the efficient cutting, with less heat generation and uniform the heat distribution.

To the best of the author's knowledge, this would be the first study comparing the heat generated during osteotomy with the conventional drill, trephine, and alveolar expander. The mean heat generated was maximum with the trephine (28.26±0.246 ºC) followed by the conventional drill (27.27±0.297 ºC) and least with alveolar expander (25.64±0.142 ºC). The heat generated with the alveolar expander was minimum and it may be because there was lateral condensation of bone rather than removal of the marrow, which generates less heat (10). The researchers have indicated that an alveolar expander is an advantageous modality for implant osteotomy since the procedure is less inva-

Table 2: *Repeated measures ANOVA for comparison of heat generated during osteotomy with conventional drill, trephine and alveolar expander*

Group	n	Min (ºC)	Max (ºC)	Baseline (ºC)	Mean (ºC)	Std. Error	95% Confidence Interval		F value	P value
							Lower Bound	Upper Bound		
Conventional drill	10	25.5	28.8	24.9	27.27	0.297	26.48	28.06	38.310	<0.001*
Trephine	10	27.4	29.2	24.8	28.26	0.246	27.78	28.74		
Alveolar expander	10	25.3	26.0	25.1	25.64	0.142	25.64	25.64		

n=number of femoral bones; *statistically significant (*P* < .05)

Table 3: *Fisher's least significant difference pairwise comparisons to find the difference in heat generated during osteotomy with conventional drill, trephine and alveolar expander*

Group (I)	Group (J)	Mean Difference (I-J)	Std. Error	*P*-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Conventional drill	Trephine	-0.990	0.389	0.023*	-1.820	-0.160
	Alveolar expander	1.630	0.386	0.014*	0.555	2.705
Trephine	Alveolar expander	2.620	0.302	<0.001*	2.028	3.212

*statistically significant (*P* < .05)

sive and easy to attempt. Alveolar expander causes minimal bone trauma with better initial healing at the bone-implant interface (18-20). Implant drills relatively produce more heat as found in the present study, and it may lead to necrosis of bone, with excess bone loss during the healing phase of implants (19).

In the study by Bhargava *et al*.(10) where they evaluate the bone loss during osteotomy using the standard drill, bone trephine, and alveolar expanders for implant placement using cone-beam computed tomography. They found that osteotomy with an alveolar expander shows the minimum bone loss as seen on cone-beam computed tomography. Expanders produce undersized implant osteotomies. More bone conservation with less heat generation during osteotomy by alveolar expander will definitely be advantageous for better primary stability and osseointegration of implants.

The present study has certain limitations, such as this is an *in vitro* animal model study and does not exactly simulate the human oral environment. In order to standardize the procedure with alveolar expanders, the internal irrigation drill and trephines were not used in the study. Further human studies should be done on osteotomy using an alveolar expander to find heat generation and its effect on osseointegration of dental implants.

Conclusion

Within its limitations, the findings of the present study indicated that the heat generated with trephine was greater compared to the alveolar expander and conventional drills. If the trephine drill is to be used, using both internal and external irrigation should be considered. Less heat generation during osteotomy by alveolar expander seems very promising and could be advantageous for the osteointegration of dental implants.

Türkçe özet: *İmplant frezi, trefan frez ve alveolar genişletici ile osteotomi sırasında üretilen ısının deneysel olarak değerlendirilmesi. Amaç: Aşırı üretilen ısı, osseointegrasyonun klinik olarak başarısız olmasına neden olabilir. Bu çalışma, osteotomi sırasında geleneksel frez, trefan frez ve alveolar genişletici ile yapılan osteotomi sırasında ortaya çıkan ısının karşılaştırılmasını amaçlamaktadır. Gereç ve yöntem: Bu in vitro çalışma, on adet sığır femur kemiği üzerinde yapıldı. Her bir femur kemiğinde, geleneksel frez, trefan frez ve alveolar genişletici kullanılarak 1.5 cm mesafede üç osteotomi bölgesi hazırlandı. Osteotomi sırasında bölge bol miktarda normal salin ile yıkandı. 3,6 mm çapında ve 11,5 mm uzunluğunda osteotomi alanları, geleneksel frez ve kemik trefanları kullanılarak hazırlandı. Osteotomi bölgesini hazırlamak için kullanılan alveolar genişletici, mevcut en yakın boyut olan 3.5 mm idi. Sıcaklık artışı bir termokupl termometresi kullanılarak ölçüldü. İstatistiksel analiz için tekrarlanan ölçümlerde ANOVA ve Fisher testi kullanıldı. Bulgular: Tekrarlanan ölçümlerde ANOVA bulguları, geleneksel frez, trefan ve alveolar genişletici ile ısı üretiminde anlamlı bir fark ortaya çıkardı (P< 0.001). Üretilen ortalama ısı en fazla trepan (28,26±0,246) ve ardından geleneksel frez (27,27±0,297) ve en az alveolar genişletici (25,64±0,142) ile elde edildi. İkili karşılaştırmalar, trefan ile karşılaştırıldığında standard frez ile osteotomi sırasında üretilen ısıda (P=0.023), alveolar genişletici ile karşılaştırıldığında geleneksel frezle (P=0.014) ve alveolar genişletici ile karşılaştırıldığında trefanda (P< 0.001) anlamlı bir fark olduğunu ortaya koymuştur. Sonuç: Alveolar genişletici ve konvansiyonel frezlere kıyasla trefan ile üretilen ısı en yüksek değerdedir. Trepan kullanılacak ise hem iç hem de dış sulama yapılmalıdır. Alveolar genişletici ile osteotomi sırasında daha az ısı üretimi, daha iyi osseointegrasyon için çok umut verici ve avantajlı görünmektedir.Anahtar kelimeler: alveolar genişletici, diş implantı, ısı üretimi, osteotomi, trefan frez*

Ethics Committee Approval: The proposal of the study was presented to Institutional Ethics Committee for ethical approval. Following approval, the study was initiated with convenience sampling.

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: SO, SKM, DB participated in designing the study. SO, HJ, SKM, DB, PK participated in generating the data for the study. SO, SKM, DB participated in gathering the data for the study. SO, HJ, SKM, DB, PK participated in the analysis of the data. SO, HJ, SKM, DB, PK wrote the majority of the original draft of the paper. SO, HJ, SKM, DB, PK participated in writing the paper. SO, SKM, DB have had access to all of the raw data of the study. SO, HJ, SKM, DB, PK have reviewed the pertinent raw data on which the results and conclusions of this study are based. SO, HJ, SKM, DB, PK have approved the final version of this paper. SKM guarantee that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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