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Intraosseous Heat Generation Using Different Drill Speeds: An In Vitro Study

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ABSTRACT

Background: To evaluate and compare the effect of drilling speed: 850rpm, 1150rpm & 1500rpm on the temperature rise at three different depth: 8mm, 10mm & 11.5mm during implant site preparation in goat mandible.

Materials & Method: Drilling was done in the posterior cortical region of 36 samples of goat mandible and randomly divided into 3 groups and 3 subgroups; group 1 included drilling with 850rpm at 8mm, 10mm & 11.5mm depth, group 2 included drilling with 1150rpm at 8mm, 10mm, 11.5mm and group 3 included drilling at 1500rpm with 8mm, 10mm &11.5mm. 2.8mm twist drill was used for drilling and thermocouple device was used for the measurement of heat generated during drilling.

Statistical Analysis: One way analysis of variance (ANOVA) was used and Shapiro Wilk test was used to check which all variables were following normal distribution.

Results: Overall higher temperature rise was seen during drilling with 850rpm and minimum temperature rise was seen during drilling with 1500rpm and significant temperature difference was seen at 10mm depth also. ($p<0.05$)

Conclusion: Significant temperature rise during implant site preparation while using slow speed drilling and temperature decreased during implant site preparation while drilling with higher speed.

Keywords: Heat generation, osteotomy, implant site preparation, osseointegration, thermocouple.

INTRODUCTION

Osseointegration in clinical dentistry depends on understanding the healing and remediation capabilities of hard and soft tissues. Its objective is a predictable tissue response to the placement of tooth analogues. Such a solution must be highly differentiated and structured according to functional requirements. Numerous research in the 1970s have introduced the concept of osseointegration, in which the bone has direct contact with the surface of the implant without the intervention of fibrous tissue.[1] There is currently a general agreement that the osseointegration situation is more stable and results in a high success rate of up to 15 years.[2] Even farther analysis of

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Osseo integrative phenomena has shown that this complex algorithm of events may be menaced by multiple factors such as frictional heat generated during implant drilling, drill speed, drill diameter, irrigation solution, drilling time, bone density, applied force, drill geometry, etc.

Intrabony temperature increase is not completely reliant on shearing energy and mechanical friction between bone and surgical drill but is also related to the heat capacity and thermal conductivity of the surrounding bone and the surgical instrument used. As a result, the time of occurrence of the highest temperature increase may be expected after the osteotomy is sheared, potentially affecting the phase of osseointegration.[3]

Several researchers have shown that heat generation is a major problem during bone drilling, as the heat is not easily removed from the drill site and therefore the bone is at significant risk of thermal damage. The literature has suggested that temperatures ranging from 56 ° C to 70 ° C are detrimental to bone tissue because alkaline phosphatase (AP) is transmogrified at this level.[4,5,6]

Bone tissues are highly susceptible to thermal damage and the temperature threshold for tissue survival during osteotomy is 47 ° C when drilling is attained for more than 1 min. Heating beyond this level may contribute to a primary failure to achieve osseointegration. The frictional heat generated at the time of surgery will always cause a certain degree of necrosis of the surrounding differentiated and undifferentiated cells, thus posing a significant risk of bone integration failure.[7]

All such implant systems in the dental market in the United States recommend drill speeds of between 1,500 and 2,000 rpm and many commercial motors do not rotate more than 1,650rpm.[8]

The intention of this in vitro study is to test and compare heat generation at variable depth with different drill speeds using a thermocouple system. Our target is to provide a safer range of drilling speed during the preparation of implants in order to avoid permanent bone necrosis, enhance the preparation of the osteotomy site and, in doing so promote implant osseointegration.

MATERIALS AND METHODS

The prospective study was done on 36 goat mandibles collected from goats slaughtered from the local butcher's shop for human consumption (Fig.1). The ethical clearance for the present study was obtained from the Ethical Committee of the college. Human bone replacement was used here because pigs, cows, goats, dogs, horses, and water buffalo exhibit both plexiform and haversian bone tissues similar to the human bone, so it is not possible to distinguish these animals from humans.[9]

The bone was kept in normal saline until it reaches at room temperature. Thermocouple probe attached to the thermocouple unit (digital thermometer) was put in the hole 1 mm from the osteotomy location (Fig.2). The thermocouple probe was positioned in the bone using a 3.2 mm twist drill at a depth of 11.5 mm from the surface of the bone, parallel to the final osteotomy location. When the thermocouple site had been cleaned, the bone was re-immersed in the water bath for 10 minutes to restore room temperature. During the study, care was taken to ensure each of the initial bone specimen must be at room temperature before drilling the osteotomy site. The orifice of each thermocouple containing thermocouple probe was separated by carding wax to prevent the irrigation fluid from entering and reducing the temperature of the bone specimen and fixed at a depth of 11.5 mm, 1 mm from the periphery of the osteotomy site. Surgical site was prepared with a 2.8 mm twist drill (Fig.3) at 8, 10 and 11.5 mm depth using a physio dispenser with variable speeds of 850, 1150 and 1500 rpm as described in the following table:

Table A: Showing the dimensions.

Group: 1 With 850rpm	Group: 2 With 1150rpm	Group: 3 With 1500rpm
At 8mm depth	At 8mm depth	At 8mm depth
At 10mm depth	At 10mm depth	At 10mm depth
At 11.5mm depth	At 11.5mm depth	At 11.5mm depth

In this study, temperature rise due to implant drill was estimated at three different speeds and three different depths. All the measurements were recorded as a linear direction of drilling. Data obtained were statistically analyzed using one-way ANOVA with Post hoc pairwise comparison using Tukey test to evaluate intergroup variations.

RESULTS

The mean and standard deviations of the cumulative temperature increase using three different drilling speeds are listed in Table 1.

Table 1: Overall temperature rise at different drilling speed

Groups	Mean Temperature rise	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
850 rpm	40.369	0.9228	0.0888	40.192	40.545	38.5	43.8
1150 rpm	39.564	1.2149	0.1209	39.325	39.804	37.7	43.6
1500 rpm	38.617	0.7029	0.0676	38.483	38.751	37.5	40.6
Total	39.515	1.2034	0.0676	39.382	39.648	37.5	43.8
P value	<0.0001 S						
Post hoc pairwise comparison using Tukey's test	1>2>3						

The osteotomy created with a drill speed of 850 rpm showed a maximum increase in temperature, while the drill speed of 1500 rpm showed a minimum generation of heat for which Post hoc Tukey's test was used.

Post hoc Tukey's test used for intergroup comparison of measurement of heat generation using 850rpm speed to drill at 8mm, 10mm and 11.5mm depth is summarized in Table 2.

The osteotomy produced to drill at a depth of 11.5 mm created more temperature and the minimum heat production was determined to drill at a depth of 8 mm.

On the other hand, when 1150 rpm was used to drill at 8 mm, 10 mm and 11.5 mm depth, the only significant difference in heat generation was seen when drilling at 8 mm and 11.5 mm depth, and the data is defined in Table 3 for that Post hoc Tukey's test was used for intergroup comparison.

Table 2: Temperature rise at different drilling depth at 850rpm

850mm	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
8mm	39.6389	0.56784	0.09464	39.4468	39.8310	38.50	40.80
10 mm	40.4444	0.64251	0.10709	40.2270	40.6618	39.30	41.70
11.5 mm	41.0222	0.93537	0.15590	40.7057	41.3387	39.40	43.80
Total	40.3685	0.92278	0.08879	40.1925	40.5445	38.50	43.80
P value	<0.0001 S						
Post hoc pairwise comparison	1>2>3						

Table 3: Temperature rise at different drilling depth at 1150 rpm

1150 mm	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
8mm	38.8056	0.72228	0.12038	38.5612	39.0499	37.70	40.30
10 mm	39.6361	1.09965	0.18328	39.2640	40.0082	37.90	42.00
11.5 mm	40.0806	1.33926	.22321	39.6274	40.5337	38.30	43.60
Total	39.5074	1.19779	.11526	39.2789	39.7359	37.70	43.60
P value	<0.0001 S						
Post hoc pairwise comparison	2,3>1						

However, Post hoc Pairwise comparison using Tukey's test again revealed significant difference in temperature rise between 8mm and 10mm drilling depth only when drilling was done at 1500rpm speed and data is depicted in Table 4.

DISCUSSION

The key purpose of dental implant placement is to achieve osseointegration. The thumb rule is therefore to prevent, or at least mitigate, essential factors impeding primary healing, i.e. related mechanical, thermal and vascular damage caused by bone drilling. Ideal atraumatic bone drilling is technically difficult. Furthermore, the heat produced is not localised at the chosen implant site and has a propensity to spread to the adjacent areas of the alveolar bone.

Table 4: Temperature rise at different drilling depth at 1500 rpm

1500 rpm	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
8mm	38.3556	0.64562	0.10760	38.1371	38.5740	37.60	40.00
10 mm	38.8833	0.68972	0.11495	38.6500	39.1167	37.80	40.60
11.5 mm	38.6000	0.69579	0.11761	38.3610	38.8390	37.50	40.20
Total	38.6131	0.70525	0.06818	38.4779	38.7483	37.50	40.60
P value	0.004 S						
Post hoc pairwise comparison	2>1*						

The higher the temperature of the bone and its length, the greater the deleterious effects of heat-induced tissue. [10] The most important drilling and drilling metrics for bone temperature rise are: drilling depth, drill flute configuration and design, cutting tool sharpness, cortical thickness variance, bone density, drilling speed, axial force, i.e. drilling strength, graduated versus one-step drilling, irrigation, machinery, torque and thrust forces.[11] Throughout that technique, the dentist changes the drilling force in accordance with his / her feeling and bone strength. When the drilling was not carried out by a dentist, the researchers tried to mimic it with a constant drilling force or a constant feed rate.[12] Since the success rate of dental implants ranges from 93.9 % to 98.7 %, the thermally induced bone necrosis, which is the primary cause of early implant failure, is known to be a rare clinical phenomena.[13] Thermal damage at the drilling site delays bone regeneration leading to hyperemia, fibrosis, osteocyte degeneration, increased osteoclast function, and necrosis.[14] In this study, Graph 1 reflected an average increase in temperature by comparing different drilling speeds, which indicates a statistically significant difference in mean temperature increase. In a study carried out by M. Sharawy et al[8] have clearly shown that using a drill speed of 2500 rpm for the preparation of the implant site will minimise bone damage, i.e. the lower the drilling speed the temperature would rise during the preparation of the implant site.

However, in a study done by Oh JH, Fang Y, Jeong SM and Choi BH[15], the author concluded that low speed drilling without irrigation may not lead to overheating during drilling. Mean temperature rise at different drilling speeds: 850 rpm, 1150 rpm and 1500 rpm are shown in Graph 2, 3 and 4 respectively and reflect a major difference in mean temperature rise at different drilling depths of 8 mm, 10 mm and 11.5 mm. A major difference was seen at a depth of 10 mm when drilling at 1500rpm. Temperature rises and temperature increase period decreased with speed and force, indicating that drilling at high speed and high load is much more advantageous than previously thought. [14,16] Brisman found that the drill speed was not the critical determinant of heat production, rather the difference in the drilling force was related to both the maximum temperature elevation and periods of temperature elevation. Increasing both the speed and the load together allowed for more efficient cutting with no significant temperature increase.[17]

Another study demonstrated that gradual drilling caused less friction and less damage to the bone compared to traditional low-speed drilling took much longer drilling time [18], Sener BC et al. in his study found that more heat was generated in the superficial part of the drilling cavity than in the bottom, i.e. the lower the depth of the drilling, the lower the temperature increase during the preparation of the implant.

The thermal conductivity of cortical bone is 0.16–0.34W/m/K and that of cancellous bone is 0.30W/m/K, which means that the heat generated during drilling is sustained even after drilling more at the cortical part of the bone. Considering the low thermal conductivity of bone, drilling would cause a cumulative heat increase, especially in the cortical bone.[19]

CONCLUSION

The present study concluded that high drilling speed induces less heat generation at the osteotomy site and thus less time for drilling and thermal necrosis can be avoided in order to establish optimal conditions for bone regeneration. It can also be inferred from this analysis that heat

generation during the preparation of the implant site depends on multifactorial units. However, not only speed, pressure and depth, but all variables must be considered prior to the preparation of the implant site so that excess heat generation does not cause irreversible bone necrosis. As in several studies, the threshold for heat-induced cortical bone tissue necrosis was concluded to be 47 ° C for one minute.
Precise steps must be taken to avoid excess heat generation, which may be dangerous and may cause bone necrosis sooner or later, resulting in failure of the principle of implant osseointegration.

The in vivo studies have shown the harmful role of heat production in subsequent bone healing and identified the critical temperature that bone can withstand without necrosis. However, in vitro studies have found that the overall concept of heat generation is considered multifactorial in nature. During this study some of the factors were difficult to control, such as hand pressure was used for drilling which might have caused unequal force during implant site preparation. Bone density standardization was also a big challenge in this study and for

future research using precise factors like force, time of drilling, time taken to return back to the baseline temperature, type of irrigation and irrigant temperature, drill material, drill shape and size, is recommended with increased sample size to overcome the results of the present study and to prevent bone necrosis and bone regeneration of human jaw bone.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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