

Temperature change in pig rib bone during implant site preparation by low-speed drilling

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ABSTRACT

Objectives: The purpose of this study was to evaluate the temperature change during low-speed drilling using infrared thermography. Material and Methods: Pig ribs were used to provide cortical bone of a similar quality to human mandible. Heat production by three implant drill systems (two conventional drilling systems and one low-speed drilling system) was evaluated by measuring the bone temperature using infrared thermography. Each system had two different bur sizes. The drill systems used were twist drill (2.0 mm/2.5 mm), which establishes the direction of the implant, and finally a 3.0 mm-pilot drill. Thermal images were recorded using the IRI1001 system (Infrared Integrated Systems Ltd.). Baseline temperature was $31 \pm 1^\circ\text{C}$. Measurements were repeated 10 times, and a static load of 10 kg was applied while drilling. Data were analyzed using descriptive statistics. Statistical analysis was conducted with two-way ANOVA. Results and Conclusions: Mean values ($n=10$ drill sequences) for maximum recorded temperature (Max $T^\circ\text{C}$), change in temperature ($\Delta T^\circ\text{C}$) from baseline were as follows. The changes in temperature ($\Delta T^\circ\text{C}$) were 1.57°C and 2.46°C for the lowest and the highest values, respectively. Drilling at 50 rpm without irrigation did not produce overheating. There was no significant difference in heat production between the 3 implant drill systems ($p>0.05$). No implant drill system produced heat exceeding 47°C , which is the critical temperature for bone necrosis during low-speed drilling. Low-speed drilling without irrigation could be used during implant site preparation.

Key words: Implant drilling. Infrared thermography. Heat production. Bone necrosis.

INTRODUCTION

Drilling procedures during dental implant site preparation may cause not only mechanical damage to the bone involved but a temperature increase in the bone adjacent to the implant site. Significant temperature increases can result in heat-induced bone injury². Thermonecrosis has been reported in the literatures¹³⁻¹⁷. Eriksson and Albrektsson¹⁴ (1983) conducted an experiment on the rabbit tibia to evaluate the effects of heat production on bone regeneration. They found that heating the implants in the rabbit tibia to a temperature of 50°C for 1 min was enough to cause 30% of the bone to be resorbed. This was a slow-developing process that extended over a period of 4 weeks. They reported that setting the temperature between 47 and 50°C for 1 min reduced significantly bone formation around the implants, while no significant effects were observed after heating up to 47°C for 1 min¹³. Eriksson and Adell¹² (1986) measured temperature

change during drilling with a thermocouple, indicating that drilling using the osseointegration technique does not impair bone regeneration due to excessive heat production^{4,12}. Watanabe, et al.²⁶ (1992) measured heat distribution in bone using thermography and found that the maximum temperature was generated when bone was cut using drills. Based on the result that maximum temperature during drilling was higher without irrigation than with irrigation, they indicated that bone temperature should not exceed the critical temperature without irrigation. Similar results have been reported by Yacker, et al.²⁷ (1996). Benington, et al.⁷ (1996) have reported that temperature rises up to 130.1°C without irrigation after monitoring changes in bone temperature during the sequence of drilling for implant site preparation by the osseointegration technique using infrared thermography. However, most studies have been performed to investigate temperature change at

a conventional drilling speed, which is over 1,000 rpm until now. This study evaluated the safety of low-speed drilling at 50 rpm without irrigation due to temperature changes.

MATERIAL AND METHODS

Pig ribs with a 2.0 mm-thick cortical bone were obtained and sliced into 10 cm-long sections. The main reason for the selection of pig ribs was their superior homogeneity in the thickness of the cortical bone. The cow or pig mandible was considered first. However, the irregular thickness of their cortical bone specimen was a definite disadvantage. Although pig ribs are weaker than the human mandible, they are excellent in homogeneity of the thickness of cortical bone. They were embedded in a resin block, and immobilized to the table. In an attempt to duplicate clinical conditions, the lower half of the specimen was soaked in a water bath at $37\pm 1^\circ\text{C}$, and the upper half of the specimen at a room temperature of 25°C . Initially, the temperature of the bone was set at $31\pm 1^\circ\text{C}$ (Figure 1).

For applying a static load, it was pressed 10 times with the same force as in the operation. About 10 kg of static load was applied. Bicon implant drill system (Bicon, Boston, MA, USA) was selected as the low-speed drill system in this study. Brånemark drill system (Nobelbiocare, Sweden) and Osstem drill system (Osstem, Seoul, Korea) were used as conventional speed drill systems. Table 1 shows the drilling systems, drill diameter size, irrigation and drill speed used in this study. The measurements were repeated 10 times and 10 kg of static load was applied while drilling.

To ensure the consistency in the drilling

procedure, one operator used a conventional dental handpiece (W&H, Bürmoos, Austria). The manufacturer's instructions were followed during implant site preparation with low-speed drilling protocol. No irrigation was performed since infrared radiation cannot transmit through water. Consequently, low-speed drilling at 50 rpm with high torque was performed because drilling without irrigation may cause bone necrosis. The temperature was recorded using a digital thermometer IRI1001 system (InfraRed Integrated Systems Ltd., UK) (Figure 2).

To prevent distraction from bur wear, brand-new burs were used. However, since the experiment was repeated 10 times, bur wear might have been a variable as experiments progressed. Brånemark drill system was used only once according to the manufacturer's instructions. The schematic diagram of the experimental implant drill systems is shown in Figure 3.

Data were analyzed using descriptive statistics. Statistical analysis was conducted with two-way ANOVA ($\alpha=0.05$).

RESULTS

Drilling at 50 rpm without irrigation did not produce overheating at the tip of the drills; temperatures changes were 1.57°C and 2.46°C for the lowest and the highest values, respectively.

The drill systems used were a 2.0 mm twist drill, which establishes the direction of the implant, and a 3.0 mm pilot drill, which progressively increases the diameter of the site.

As expected, the conventional systems did not increase the temperature of pig cortical bone up to the critical point of 47°C , which was reported

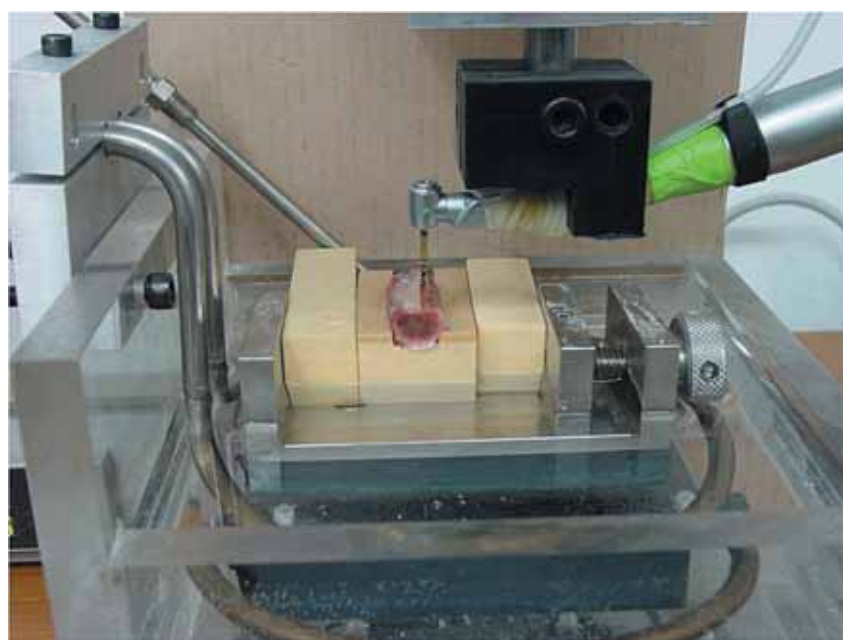


Figure 1- Pig rib immobilized to resin block



Figure 2- Infrared thermography measured the temperature changes

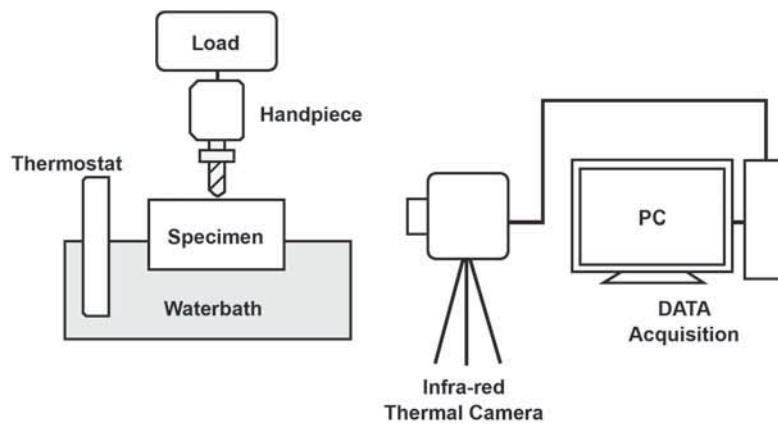


Figure 3- Schematic diagram of the experimental system

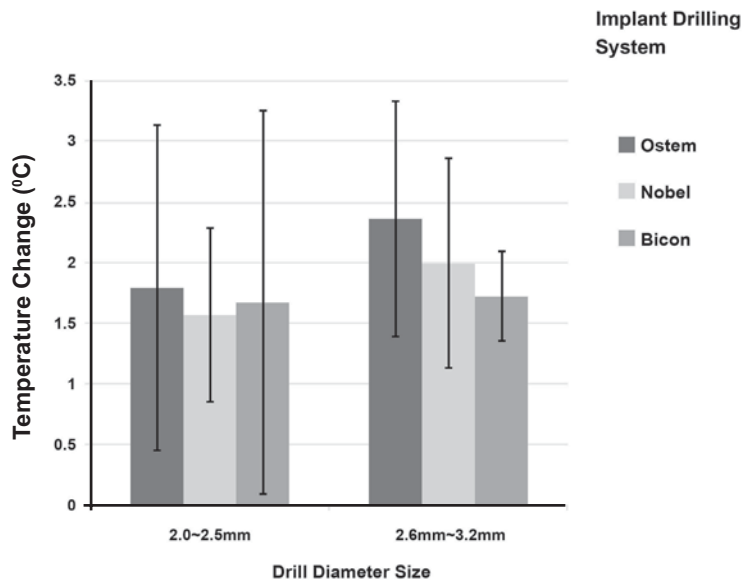


Figure 4- Relationship between drill diameter and bone temperature

Table 1- Implant drilling systems tested in the study

Implant System	Drill size	Irrigation	Drill speed (rpm)	
			Tested	Recommended
Brånemark	2.0 mm, 3.0 mm	No	50	1,200
Osstem	2.0 mm, 3.0 mm	No	50	1,200
Bicon	2.0 mm, 3.0 mm	No	50	50

Table 2- Mean baseline temperature, maximum temperature, and temperature difference according to implant drill systems and drill diameter

System	Diameter (mm)	Mean Baseline Temp. (°C)	Mean Max. Temp. (°C)	Mean T (°C)
Brånemark	2	30.99	32.56	1.57
	3	30.59	32.58	1.99
Osstem	2	31.74	33.53	1.79
	3	31.2	33.56	2.46
Bicon	2.5	30.61	32.28	1.67
	3	30.45	32.17	1.72

by Eriksson, et al.⁴ (2007). The low-speed drilling showed low temperature change as well. The results are summarized in Table 2.

No implant drill systems produced heat exceeding the critical temperature. There were no significant differences in heat production among the 3 systems. Temperature became higher as drill diameter increased. The implant drill system and the drill diameter were defined as independent factors. There was no significant difference among the 3 implant drill systems ($p > 0.05$). There was statistically significant difference in heat production according to drill diameter ($p < 0.05$). The larger the drill diameter was, the higher the bone temperature because the greater bone volume to be cut created more friction during the drilling procedure. Figure 4 shows the relationship between drill diameter and bone temperature.

DISCUSSION

The purpose of this study was to investigate the heat produced by 3 individual implant drill systems after repeated drilling including low-speed drilling technique without irrigation.

The concept of low-speed drilling has been suggested as an alternative to the conventional procedure. This technique has pros, including easy manipulation of drilling path, and cons, including longer drilling time. The strength of low-speed drilling can be easily controlled to maintain the path of drilling. Conventional drilling can change its drilling path on its own when the drill encounters a dense cortical bone. Low-speed drilling can inform the operator that the path has changed so that the operator can correct it. Ericsson and

Albrektsson¹⁴ (1983) demonstrated that heating bone to 47°C for 1 min reduced the amount of bone that grew into the implant. They established that the threshold level for bone survival during implant site preparation is 47°C, keeping drilling time below 1 min. Bachus, et al.⁵ (2000) have demonstrated that through the application of a strong force to the drill, both the maximum cortical temperature above 50°C and its duration can be effectively reduced and subsequently decrease the potential for thermal necrosis in the neighboring cortical bone.

Multiple factors have been implicated in the production of heat during osteotomy preparation. These factors include drill speed^{9,24,25}, cortical thickness^{3,23,27}, drill sharpness^{1,11}, drill force^{1,18}, drill depth¹¹, drill design^{11,18}, drill diameter¹¹, graduated compared with 1-step drilling^{11,27}, and irrigation^{6,15,22}. Bur wear has been considered as well. Chacon, et al.¹⁰ (2006) have concluded that bur wear and bur geometry play a major role in heat production. From a heat generation standpoint, Misir, et al.²³ (1972) conclude that preparing an implant site with using surgical drill guides generates heat more than classical implant site preparation regardless of the irrigation type.

Bone temperature can be measured by two methods. One is the method using a thermocouple embedded in bone, and the other is infrared thermography. Thermography detects the radiant infrared value of a subject, discriminates the distribution of temperature as a visible image, and expresses it in color on a monitor. Thermography has a few advantages: its ease of use and real time measurement. Although thermography is limited in accuracy with an error of up to $\pm 1^\circ\text{C}$, this error is

not large enough to affect the conclusion. Infrared thermography was used in this study because the method using a thermocouple required too much effort to set up the instrument, and also because it was unclear whether this method was more accurate.

Implant site preparation techniques currently in use involve drilling at speeds of 1,000 to 1,500 rpm to prepare potential recipient sites. The mechanical and thermal damage to the tissue surrounding the implant during drilling could have a destructive effect on the initial state of the cavity housing the implant^{19,20}. In this study, gradual drilling caused less friction, and thus less trauma to the bone. Compared to conventional drilling, low-speed drilling took much longer duration of drilling time. A single drill with the same size (2 mm and 3 mm) was used for each implant drill system except for the Brånemark system. Different Brånemark system burs with the same size were used only once according to the manufacturer's protocol, as previously reported by Chacon, et al.⁹ (1996). Those authors showed that temperature increases when drills were used multiple times.

Clinicians sometimes need a small amount of bone graft material during implant surgery. Some use alloplastic material and others take autogenous bone from the patient's donor site. Others have used bone was collected with new devices during surgery for bone graft. This is particularly important because clinically autogenous bone has been reported to be the ideal defect filler. Bone collected during low-speed drilling may be easier to manipulate than bone collected by other methods, such as bone trap and bone collector. The effects of drill speed on heat production have been studied to improve irrigation delivery systems^{19,20}. The fact that the drill is used at low speeds helps improving the quality of bone obtained, as shown by light microscopic and ultrastructural analysis⁴, and the biological conditions of bone tissue in the new-alveolar sockets. However, this method has a disadvantage in that friction may possibly traumatize the collected bone as well as the surrounding bone because it cannot be irrigated during drilling. To prevent bone necrosis, clinicians should drill at a low speed between 20 and 100 rpm without irrigation. As the drill completes considerably more rotations at high speed than at low speed, yet advances the same distance, high-speed drilling shreds the tissue to a greater extent. The effects of drill speed on heat production have been studied to improve irrigation delivery systems²⁵. Several authors^{8,21} have compared bone particles obtained from different commercial bone traps and examined differences in the percentage of bone to coagulum. Bone trap design also affects the mass and the nature of the collected tissue²⁸. The presence of microorganisms found during the collection process can be very high due to saliva retention with some bone traps⁸. However, the

displaced tissue retained in the drill bit during low-speed drilling was very easy to collect, reducing saliva contamination.

In the present study, low-speed drilling without irrigation did not increase bone temperature. The small number of data included in this study limits the extrapolation of results. A randomized clinical trial comparing low-speed drilling and conventional speed drilling under controlled clinical conditions should be conducted to provide further evidence of the effect of low-speed drilling protocols. Animal studies may also be helpful in gathering histological data on bone regeneration from collected bone during low-speed drilling.

CONCLUSIONS

Within the limitations of this study, it is suggested that low-speed drilling at 50 rpm without irrigation may not significantly increase bone temperature, and that there may be a direct relationship between bur diameter and bone temperature. This may explain why we start drilling with the smallest-sized bur and increase the bur size progressively during implant surgery.

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