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*Evaluation Study*

# INFRARED THERMOGRAPHIC EVALUATION OF TEMPERATURE MODIFICATIONS INDUCED DURING IMPLANT SITE PREPARATION WITH CONICAL DRILLS

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## ABSTRACT

Several research studies have explored the impact of drilling on bone healing. Various factors have been identified as affecting the increase in temperature during surgical preparation for implant placement. These factors include drill design, material, depth of drilling, sharpness of the cutting instrument, drilling velocity, pressure exerted on the drill, preference for graduated or one-step drilling, intermittent versus continuous drilling, and the presence or absence of irrigation. This research aimed to measure the temperature fluctuations in cortical bone and at the tip of the drills while preparing implant sites using a conical implant drill. The drill system was evaluated in a laboratory using cortical bone from bovine femurs. This system used a conical drill with triple twist and triple twist drills. Site preparation commenced, and the temperatures of the cortical bone and the tip of the drill were recorded using infrared thermography**.** The average temperature recorded in the cortical bone during implant preparation was 30.2±0.5°C while the average temperature recorded at the tip of the drill during implant site preparation was 32.1±0.5°C. No statistically significant differences were observed in the temperatures recorded in the cortical bone and at the tip of the drill. The experimental setup employed in this study successfully measured the temperature changes in both the cortical bone and the tip of the drills. The temperature changes at the drill's tip seemed to be related to the tool's geometric shape. The results of this study show that drill geometry significantly impacts how much heat is produced when implant sites are being prepared. The drill's design or form could explain the increased temperature at the drill's tip.

**KEYWORDS**: *dental implant, drilling, heat generation, osseointegration, infrared thermography*

## INTRODUCTION

Dental implants have become a popular and reliable option for replacing missing teeth, with high success rates (1). They depend mainly on achieving adequate bone healing and establishing osseointegration (2). The complex process of bone healing around dental implants includes the activation of periosteal and endosteal lining cells, the growth and differentiation of pre-osteoblasts into osteoblasts, the production and mineralization of osteoid matrix, and the final organization of the bone-implant interface (3, 4). Primary healing must occur for a dental implant to be successful (3). Thus ensuring the implant location is prepared without stress (5).

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While creating the implant site, friction between the drill and bone inevitably generates heat. If not properly managed, this heat can lead to a detrimental complication known as thermal damage. On the other hand, heat produced by drilling during implant site preparation may cause bone damage. Research suggests that temperatures exceeding 47°C for over a minute can be harmful. Higher temperatures and extended thermal exposure enhance this danger and can compromise bone tissue repair (6), delayed healing, bone loss, and pain. In addition to mechanically harming the affected bone, dental site preparation raises the temperature of the surrounding bone in the vicinity of the implant site.

Over the past ten years, numerous researchers have endeavored to characterize the interface structure between implants and bone (4, 7, 8). A predictable degree of success in integrating implants with bone has been attained through implementing a gentle surgical technique under sterile conditions, a healing period devoid of loading, and introducing macroretentive commercially pure titanium implants (9). A few studies have examined how drilling affects bone mending (10); after drilling holes in the bone and implanting dental crowns, cellular and molecular reactions begin, constituting the wound-healing response (3). An approximate temperature of 56°C is produced during surgical preparation for implant insertion. Interestingly, alkaline phosphatase becomes denatured at this temperature, which slows down the mending of bones (11).

Necrosis brought on by high temperatures has previously been documented in the literature (12). The authors of this study have previously utilized a thermocouple and infrared thermographic to measure temperature changes induced during implant site preparation in a bovine rib model (2, 12). Subsequently, they developed a model to visualize temperature changes during implant site preparation under saline irrigation. A study employing external irrigation during the drilling of bovine bone revealed that temperature increases, as detected by the thermocouple, were notably higher in the cortical bone and escalated with an increasing number of drill uses (13).

This study aimed to compare temperature variations, assessed using infrared thermography, generated under an external irrigation system during bone preparation for implants utilizing a conical implant drill.

## MATERIALS AND METHODS

The effectiveness of the implant drills was assessed using bovine femoral cortical bone in a laboratory setup. The lower portion of the bone was immersed in a temperature-controlled saline solution at 26.0°C. Site preparation commenced once the internal temperature of the bone, measured via infrared thermography, equaled the bath temperature of 26.0°C±0.1°C. Saline solution at room temperature was used for continuous irrigation during drilling at a 50 mL/min rate. Thermal measurements were conducted in a climate-controlled environment (temperature: 23-24°C, relative humidity: 53±5%, and no direct airflow onto the bone). The implant drill system evaluated was a triple twist system (Isomed System, Due Carrare, Padova, Italy). Four sets of new drills were assessed, and all drilling procedures were conducted at a speed of 800 revolutions per minute (rev/min). Intermittent drilling occurred at 2-second intervals while the bone remained submerged in the thermostat-controlled saline bath.

An experienced implantologist (AS) performed all drilling to ensure the closest possible replication of real-life scenarios. Thermal image series during implant site preparation were captured using a 14-bit digital infrared camera (FLIR SC3000 QWIP, FLIR Systems, Danderyd, Sweden) (Fig. 1).

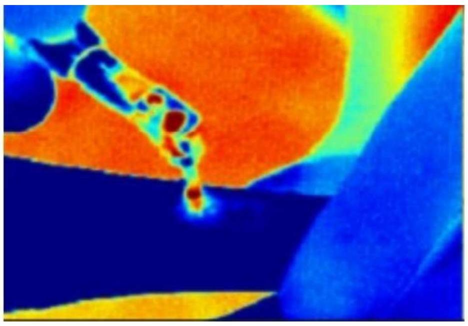

**Fig. 1.** *Thermogram illustrating the area of maximal thermal emission of cortical bone and drill during the use of a drill.*

The acquisition parameters included a 320x240 Focal Plane Array, 8-9 µm spectral range, 0.02 K Noise Equivalent Temperature Differences (NETD), 50 Hz sampling rate, optics with a germanium lens, aperture settings at f/20 and f/1.5. The camera was positioned 0.50 meters away from the bone to achieve maximum spatial resolution. Images were acquired at a rate of 25 per second and later realigned using an edge-detection-based method implemented in proprietary software. Temperature variations in the cortical bone and at the tip of the drill were determined based on these images.

*Statistical evaluation*

The primary outcome measures were the changes in temperature (both mean and maximum) of the cortical bone at the implant site and at the tip of the drill, expressed as the mean±standard deviation of the three drills for each system, measured upon completion of implant site preparation. The thermal image video also allowed for assessing variations in drilling durations between the two systems. The significance of observed differences was assessed using Student's t-test, with a two-tailed significance level of <0.05 considered statistically significant. Statistical analysis was evaluated using SPSS 14 for Windows.

**RESULTS**

Thermal image series during implant site preparation were captured and evaluated (Fig. 1). The average temperature generated in the cortical bone during implant preparation (Fig. 2, 3) was 30.5±0.5°C at the drill tip was 31.2±0.5°C.

**Fig. 2**. *Area of cortical bone during the initial phase of implant bed preparation.*

**Fig. 3**. *Area of cortical bone during the end phase of implant bed preparation.*

The maximum and mean temperature variations that were seen during drilling in the designated area were displayed in Table I. The highest temperatures that were measured were below the level that is thought to be dangerous for bone health.

**Table I.** *Maximum and mean temperature variations seen during drilling*

| Basal bone temperature 26°±0.5°C | | |
|---|---|---|
| | Max T cortical bone °C | Max T apical portion of drill °C |
| Temperature | 30.5±0.5°C | 31.2±0.5 °C |

*Statistical evaluation*

Data analysis statistically revealed no differences between the temperature measurements at the cortical bone and the tip of the drill ($p \geq 0.05$).

## DISCUSSION

The temperatures produced during implant site preparation rise with increased drill usage, according to a previous study (13). Many more elements have also been shown to influence the increase in temperature during the surgical preparation for implant insertion. These variables include drill material (10, 14), drill geometry (15, 16), drilling depth (17), sharpness of the cutting tool (18), drilling speed (19), pressure applied to the drill (18), use of graduated versus one-step drilling (20), intermittent versus continuous drilling (21), and use of internal or external irrigation (22). Various drill designs and geometries have been suggested over the years (17, 23). Primarily, they are based on conventional geometrical shapes used to drill metals.

According to Matthews and Hirsch (17), under certain surgical circumstances without external irrigation, cortical temperatures in a human femoral cortex model approached 100°C during osteotomy preparation. Drills' overall performance may be affected by several factors, including the material's durability. Recent studies have suggested that implant failures may be influenced by the impact of drilling on bone (22). As a result, the investigation of the localized consequences of drilling was the particular emphasis of this work. Heat generation is one clinically significant and sometimes dangerous side effect of drilling. The soft tissues covering the bone may receive heat from the metal drill head in the cortical bone. Many drill designs, geometries, and metals have been presented over the years (23, 24), each with claimed benefits, although most are based on conventional drill geometry.

According to certain research, heat produced during drilling operations is a significant factor in implant failure (25, 26). This is because the heat generated within the bone may cause the periosteum to lose vitality (27), the bone to become devascularized, and alkaline phosphatase denaturated.

When preparing the implant bed, avoiding bone damage from both heat and mechanical forces is critical. During surgery, rotary instruments are the main tool used to cut bone. These instruments can produce heat and damage. Additionally, clogging the cutting flutes in these devices may result in ineffective cutting (28). Various clinicians have been known to apply different pressures to the drill, and this variability may be related to the heterogeneous structure of bone tissue.

The model system of this study performed a good job of evaluating temperature variations in the drill tip and cortical bone, and it showed a relationship with drill shape. The results of this investigation highlight how important drill geometry is for producing heat when preparing an implant site. Interestingly, neither the degree of drill use nor the possible effects of sterilization or disinfection were considered in this investigation. Although various factors can affect bone temperature and drill-cutting efficiency separately, their combined effect is clinically significant. The temperature rise during surgical preparation for implant placement is influenced by a number of factors, including the geometry of the drill flute, the depth of the drilling, the sharpness of the cutting tool, the speed at which the drilling is done, the pressure at which the drill is operated, whether graduated or one-step drilling is preferred, whether intermittent or continuous drilling is carried out and whether internal or external irrigation is used. Given these variables, it is possible to speculate that temperatures in clinical settings may be higher than those recorded in this study.

## CONCLUSIONS

In conclusion, the drill's configuration greatly impacts how much heat is produced while drilling. The heat recorded on the cortical bone and drill tip was significantly lower than the bone damage when using a conical implant drill with an external irrigation system.

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