Infrared Thermographic Evaluation of Temperature Modifications Induced during Implant Site Preparation with Cylindrical versus Conical Drills

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ABSTRACT

Background: A few studies have investigated the influence of drilling on bone healing. Many factors have been reported to influence temperature rise during surgical preparation for implant placement: drill geometry, drilling depth, sharpness of the cutting tool, drilling speed, pressure applied to the drill, use of graduated versus one-step drilling, intermittent versus continuous drilling, and use or not of irrigation.

Purpose: The objective of this study was to quantify the temperature changes in cortical bone and at the apical portion of the drills during implant site preparation with a cylindrical implant drill versus a conical implant drill.

Materials and Methods: Two implant drill systems were evaluated in vitro using bovine femoral cortical bone. The two implant drill systems evaluated in this study were system A (a cylindrical drill with triple twist drills) (Bone System, Milano, Italy) and system B (a conical drill with quadruple twist drills) (Bone System). Site preparation began, and the temperature of the cortical bone and at the apical portion of the drill was measured by the infrared thermography.

Results: The mean temperature produced in the cortical bone during implant preparation was 31.2 ± 0.5°C for the cylindrical drills and 29.1 ± 0.6°C for the conical drill. The mean temperature produced in the apical portion of the drill during implant site preparation was 32.1 ± 0.7°C for the cylindrical drill system and 29.6 ± 0.6°C for the conical drill. Statistically significant differences were found in the temperature measurements in the cortical bone in the two groups ($p < .05$). A statistically significant difference was observed for the temperature measurements in the apical portion of the drill in the two groups ($p < .005$).

Discussion: The model system used in this work was able to evaluate the temperature in the cortical bone and in the apical portion of the drills; the temperature modifications in the apical portion of the drill seemed to be correlated to the drill geometry. The results of the present study showed that drill geometry seems to be an important factor in heat generation during implant site preparation.

Conclusion: The drill geometry could explain the increased temperature in the apical portion of the drill.

KEY WORDS: dental implant, drilling, heat generation, infrared thermography, osseointegration

INTRODUCTION

Osseointegrated implants have a very high long-term success rates.[1] The bone healing around dental implants is a complex phenomenon. It requires the proliferation and differentiation of pre-osteoblasts into osteoblasts,

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along with the activation of periosteal and endosteal lining cells, and the production and mineralization of osteoid matrix followed by the organization of the bone-implant interface.[2] The success of a dental implant depends, in part, on its capability to achieve primary healing.[2] Therefore, atraumatic implant site preparation is important.[3] Implant site preparation with drills generates heat and can produce bone necrosis, which increases exponentially with the increase of temperature and with the duration of the thermal injury.[4] In fact, dental site preparation can cause not only a mechanical damage to the bone involved, but also a temperature increase in the bone adjacent to the implant site.

Over the past decade many investigators have tried to define the structure of the implant-bone interface.[5] By the use of a gentle surgical technique in sterile conditions, a healing period free of loading, and the development of macroretentive commercially pure titanium implants, a predictable level of success in the integration of implants with bone has been achieved.[6] A few studies have investigated the influence of drilling on bone healing. After the bone drilling and the placement of dental implants, a sequence of cellular and molecular events initiates which represents a combined response of wound healing.[2] The effect of temperature generated during the surgical preparation for implant placement is generally regarded to be in the region of 56°C, and in fact at 56°C the alkaline phosphatase is denatured and bone healing is slowed down.[2,4–6] Necrosis as a result of elevated temperatures has been previously reported in the literature.[4] Previous work by the current authors has involved the use of a thermocouple to measure the temperature change induced during implant site preparation in a bovine rib model.[7] A model subsequently has been developed to permit this technique to visualize the temperature changes during implant site preparation under saline irrigation. A study that used external irrigation during drilling of bovine bone showed that the temperature increases, observed with the thermocouple, were significantly higher in the cortical bone, and increased with an increasing number of drill uses.[7]

The aim of this study was to compare the temperature modifications, evaluated using infrared thermography, that were generated under an external irrigation system during bone preparation for implants using a cylindrical versus a conical implant drill.

MATERIALS AND METHODS

The two implant drills were evaluated in an in vitro system using bovine femoral cortical bone. The inferior half of the bone was submerged in a temperature-controlled saline bath (26.0°C). Site preparation began when the internal temperature of the bone, as measured by the infrared thermography, reached the bath temperature of 26.0 ± 0.1°C. Normal saline solution at the same temperature was used to irrigate the site and was maintained continuously throughout drilling at a rate of 40 mL/min. Thermal measurements were performed in a climate-controlled room (temperature: 23–24°C, relative humidity: 50 ± 5%, and no direct ventilation on the bone).

The two implant drill systems evaluated were a cylindrical drill (3.7 mm) with a triple twist system (Bone System, Milano, Italy) and a conical drill (3.7 mm) with a quadruple twist system (Bone System). Three sets of new drills were evaluated for each system.

Thirty-six implant sites were prepared at a speed of 800 rev/min. Intermittent drilling was performed at 2-second intervals while the bone was still in the thermostat-controlled saline bath. All drilling was performed by a single experienced implantologist (A.S.) in order to most accurately reproduce a real-life situation. A total of six harvested femoral bone and six new drills for implants with external irrigation (Bone System) were used in this study. Thermal image series during implant site preparation were obtained using a 14-bit digital infrared camera (FLIR SC3000 QWIP, Flir Systems, Danderyd, Sweden). The acquisition parameters were 320×240 focal plane array, 8–9 μm spectral range, 0.02 K noise equivalent temperature differences, 50 Hz sampling rate, optics, germanium lens, f 20, and f/1.5. The camera was set 0.50 m away from the bone for maximum spatial resolution. Images were acquired at a rate of 25 per second and subsequently realigned using an edge-detection-based method implemented in an in-house software. Temperature changes in cortical bone and in the apical portion of the drill were determined using these images.

Statistical Evaluation

The main outcome measurements were temperature modifications (mean and maximum for the area of interest) of the cortical bone at implant site and apical portion of bur expressed as mean ± standard deviation of the three burs for each drill system measured when

TABLE 1 Basal Bone Temperature 26 ± 1°C

	Maximum Temperature of Cortical Bone (°C)	Maximum Temperature of the Apical Portion of Drill (°C)	Mean Temperature of Cortical Bone (°C)	Mean Temperature of the Apical Portion of Drill (°C)
Temperature cylindrical drill	32.4 ± 0.4	32.8 ± 0.6	31.2 ± 0.5	32.1 ± 0.7
Temperature conical drill	30.1 ± 0.4	31.8 ± 0.5	29.1 ± 0.6	29.6 ± 0.6

Temperature values after the use of cylindrical and cortical drills.

the implant site preparation was completed. The video of the thermal images will also permit the evaluation of differences in drilling times for the two burs. The significance of the differences observed was evaluated with Student's *t*-test (a two-tailed significance level <.05 was regarded as statistically significant). Analysis was performed using SPSS 14 for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS

The mean temperature produced in cortical bone during implant preparation was 31.2 ± 0.5°C for the cylindrical drill and 29.1 ± 0.6°C for the conical drill (Figs. 1 and 2). The mean temperature produced in the apical portion of the drill during implant preparation was 32.1 ± 0.7°C for the cylindrical drill (Fig. 3) and 29.6 ± 0.6°C for the conical drill (Fig. 4). In Table 1, maximum and mean temperature changes that were recorded in the area of interest during drilling were reported. The maximum temperatures were below the level considered dangerous for bone vitality.

Statistical Evaluation

Statistically significant differences were found in the temperature measurements in the cortical bone in the two groups ($p < .005$). A statistically significant difference was observed for the temperature measurements in the apical portion of the drill in the two groups ($p < .005$).

DISCUSSION

A previous study[7] reported that the temperatures generated during implant site preparation increase with an increasing use of the drill. In this study, infrared thermography was used because it was more precise. In fact, the position of the thermocouples, used in a previous study from our laboratory, is imprecise and is influenced by many variables. Moreover, this imprecision can influence the temperature evaluation, and, in fact, the temperature evaluated with the thermocouples depends on the bone quantity and quality between implant site and thermocouples. Many other factors have been reported to influence the temperature rise during the surgical preparation for implant placement, including drill geometry,[8,9] drilling depth,[10] sharpness of the cutting tool,[11] drilling speed,[12] pressure applied to the drill,[11] use of graduated versus one-step drilling,[13] intermittent versus continuous drilling,[14] use of internal or external

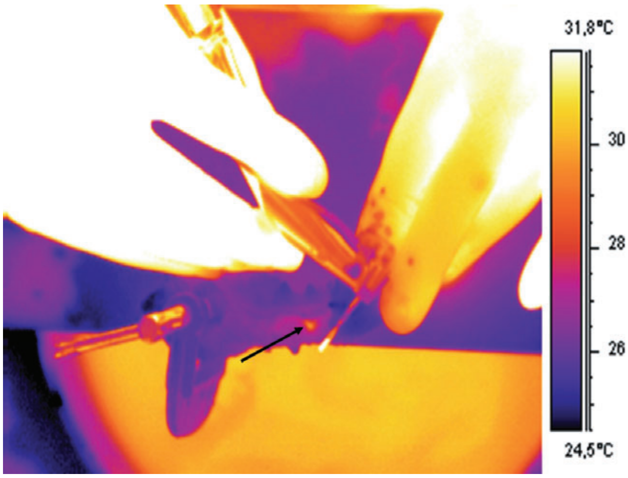

Figure 1 Thermogram illustrating the area of maximal thermal emission of cortical bone after use of a cylindrical drill (*arrow*).

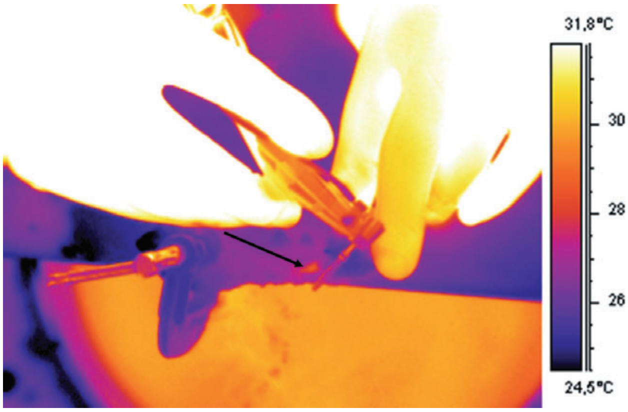

Figure 2 Area of cortical bone after use of a conical drill. The arrow illustrates the temperature increase observed at this point.

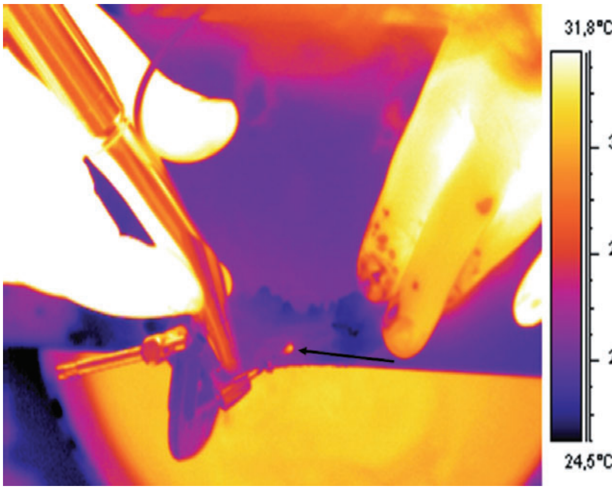

Figure 3 Thermogram illustrating the area of maximal thermal emission in the apical portion of cylindrical drill after use (*arrow*).

irrigation,[15] and mechanical properties and quality on drill performance material selection and quality on drill performance.[16] Various drill designs and geometries have been suggested over the years.[17,18] For the most part, they are based on conventional geometrical forms used for drilling of metals. Matthews and Hirsch[12] demonstrated, during osteotomy preparation in a human femoral cortex model, that under certain surgical conditions where no external irrigation was employed cortical temperatures were higher than 100°C. An important factor that could affect the final performance of the drill is the toughness of the materials used for construction. Recent studies demonstrated that the effects of drilling on bone can favor implant failures.[19] For this reason, this study focused on the local effects of drilling. One clinically important, potentially harmful effect of drilling is the generation of heat. This heat is generated by the metal drill head in the

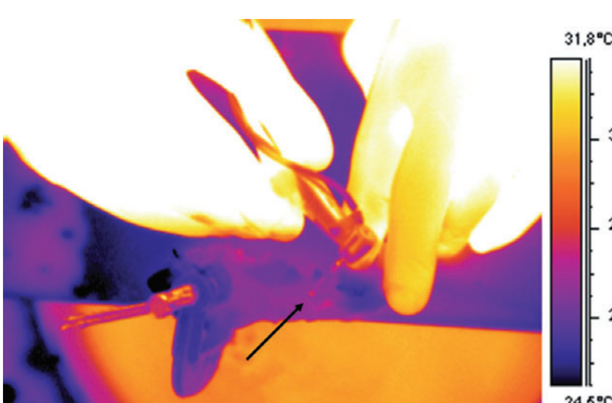

Figure 4 Thermogram illustrating the area of maximal thermal emission in the apical portion of conical drill after use (*arrow*).

cortical bone, and from there to the soft tissues covering the bone. Many different drill designs, geometries, and metals have been suggested over the years,[17,18] each with its own claim to success, but most of them based on conventional drill geometry.

Some studies have hypothesized that heat generation during drilling procedures plays a significant role in implant failure.[20,21] In fact, the heat of bone induces a denaturation of alkaline phosphatase, bone devascularization, and loss of vitality of the periosteum.[22,23] Thermal and mechanical damage to the bone must be reduced during preparation of the implant bed. The method of cutting bone during surgery is by rotary devices. These produce heat and trauma, and may cut inefficiently because the cutting flutes become clogged.[24] Differences have been described in the pressures applied on the drill by the different clinicians. These differences may also be related to the nature of bone, which is not homogenous.

The model system used in this work was able to evaluate the temperature in the cortical bone and in the apical portion of the drills and to demonstrate that these temperature modifications were correlated to the drill geometry. The results of the present study demonstrate that the characteristics of drill geometry are an important factor in heat generation during implant site preparation. In the present study, no consideration was given to either the influence of sterilization and disinfection, or the extent of drill use. Although many factors may play a role in drill-cutting efficiency and bone temperature, it is their net effect that has a clinical relevance. In fact, many factors have been reported to influence temperature rise during surgical preparation for implant placement: drill flute geometry, drilling depth, sharpness of the cutting tool, drilling speed, pressure applied to the drill, use of graduated versus one-step drilling, intermittent versus continuous drilling, and use of internal or external irrigation. For these reasons, it can be hypothesized that in clinical practice the temperature is higher with that observed in the present study. The results of this study are influenced also by the geometry and number of flutes. Another consideration was that the baseline temperature and the temperature of the coolant, 26°C, were different from what would be generally found in vivo. This difference is not important because in this study only the increase of temperature was evaluated. The osteotomies were carried out by a single operator (A.S.) in such a way as to simulate what happens in clinical practice. In both groups, the temperatures reached during the osteotomies were well below any potentially harmful temperature for the bone.

In conclusion, drill geometry plays an important role in heat production. The temperatures that were generated under external irrigation systems during bone preparation for cylindrical implant drill were significantly higher than those generated with the use of conical implant drill.

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