Experimental Analysis of Temperature Differences During Implant Site Preparation: Continuous Drilling Technique Versus Intermittent Drilling Technique

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Implant site preparation through drilling procedures may cause bone thermonecrosis. The aim of this in vitro study was to evaluate, using a thermal probe, overheating at implant sites during osteotomies through 2 different drilling methods (continuous drilling technique versus intermittent drilling technique) using irrigation at different temperatures. Five implant sites 13 mm in length were performed on 16 blocks (fresh bovine ribs), for a total of 80 implant sites. The PT-100 thermal probe was positioned 5 mm from each site. Two physiological refrigerant solutions were used: one at 23.7°C and one at 6.0°C. Four experimental groups were considered: group A (continuous drilling with physiological solution at 23.7°C), group B (intermittent drilling with physiological solution at 23.7°C), group C (continuous drilling with physiological solution at 6.0°C), and group D (intermittent drilling with physiological solution at 6.0°C). The Wilcoxon rank-sum test (2-tailed) was used to compare groups. While there was no difference between group A and group B (W = 86; P = .45), statistically significant differences were observed between experimental groups A and C (W = 0; P = .0001), B and D (W = 45; P = .0005), and C and D (W = 41; P = .003). Implant site preparation did not affect the overheating of the bone. Statistically significant differences were found with the refrigerant solutions. Using both irrigating solutions, bone temperature did not exceed 47°C.

Key Words: bone, implant, stress, implant survival, implant-site preparation, surgical drills

INTRODUCTION

Implant site preparation through drilling procedures may not only cause mechanical damage to the bone involved but also a temperature increase in the bone adjacent to the implant site, which can result in thermonecrosis.\(^1\) Thermally induced necrosis has been reported as one of the main causes of dental implant failure during osseointegration.\(^2\)–\(^5\) According to 3 studies,\(^6\)–\(^8\) a temperature of 47°C for at least 1 minute was identified as a limit threshold to the bone survival. Although intimate contact between the drill and bony wall is mandatory, it is usually considered the main reason for heat generation. Besides, the presence or absence of irrigation during the drilling\(^9\); drill geometry and design\(^10,11\); drill wear\(^12,13\); sharpness of the cutting tool\(^14,15\); bone density\(^16\); drilling speed, axial force, and pressure applied to the drill\(^17\)–\(^21\); and internal and external irrigation\(^22\) have been investigated by many authors as important factors affecting the development of frictional heat. Nevertheless, few studies have investigated the involvement of the technique in preparing the implant site.\(^23\)–\(^27\)

Usually, the preparation of an implant site consists of the use of a series of drills, each of increasing diameter\(^2,6,8\); the aim is to contain the friction generated during the procedure.\(^28\) Nevertheless, Lucchiari et al\(^29\) demonstrated that the differences in temperature variations generated by the standard technique versus the single-drill technique are clinically irrelevant.

During the preparation of multiple implant sites, 2 different drilling techniques can be adopted: continuous or intermittent. Many authors observed that the heat generated during implant site preparation is directly proportional to the time of exposure to the friction forces produced during drilling\(^9\); moreover, higher temperatures are associated with longer preparation times.\(^21,30,31\) Conversely, few studies have compared the 2 different methods.

The aim of this in vitro study was to analyze temperature variations generated by continuous and intermittent drilling techniques to prepare multiple implant sites using 2 different refrigerant solutions at different temperatures. The null hypothesis was that no significant difference in temperature...
variation would be generated by continuous and intermittent drilling techniques with irrigation at different temperatures.

MATERIALS AND METHODS

The in vitro experimental study was designed to reproduce the clinical condition of an edentulous mandibular bone by using bone samples dissected from fresh bovine ribs. Bovine ribs represent a well-established bone model for human jaw because of similarities in bone density, thermal conductivity and the ratio between cortical and cancellous bone. \(^1,11,14,18,28\) Twenty ribs were dissected through a cutter and a multi-rosette (Meisinger HM 141F023 diameter 0.3 mm; Hager & Meisinger GmbH, Neuss, Germany) mounted on a handpiece (W&H Dentalwerk Bürmoos GmbH, Bürmoos, Austria) in 16 blocks (40 \(\times\) 40 \(\times\) 20 mm). The blocks of bone were prepared as edentulous, and 5 implant sites were prepared on each block for a total of 80 sites. One site/block was set up for the thermal probe (Figure 1). The measurements were carried out using a PT-100 thermal probe (Pico Technology, Tyler, Tex) (temperature range \(-40^\circ C\) to \(+80^\circ C\); probe error \(\pm 0.45^\circ C\)), a resistance thermometer equipped with a platinum sensor. The center of the hole containing the thermal probe was positioned at 5 mm from each site (Figure 2). The probe was introduced into the bone through the set-up hole and thermally coupled to the inner bone wall through a layer of thermally neutral “thermal grease” (AOS 52029, AOS Thermal Compound, Eatontown, NJ). The thermal insulation was ensured by a coating of 2-component epoxy resin able to thermally isolate a thin layer in the range of \(-200\) to \(+200^\circ C\). The temperature was measured as electrical resistance (ohms [\(\Omega\)]) by the probe and recorded at 1-second intervals by a digital multimeter (Mod. FLUKE 89 Series IV, Fluke Europe BV, Eindhoven, Netherlands) converted into Celsius degrees according to the equation for linearizing the same software.

After excision from fresh bovine ribs, the blocks were frozen and stored at \(-20^\circ C\) up to use. Then they were thawed by immersion in a temperature-controlled saline bath (26.0\(^\circ C\) \(\pm\) 1\(^\circ C\); site preparation began when the internal temperature of the bone was in equilibrium with the bath temperature. All procedures, related to the preparation of implant sites were performed by a single expert operator. The sites were 13 mm in length and 2 mm in diameter; a cutter pilot drill (Biomax 3i, Biomet 3i Implant Innovations, Palm Beach Gardens, Fla) was used. The handpiece was connected to an Implantmed motor (W&H Dentalwerk Bürmoos GmbH) with a speed of 1200 rpm and a torque of 35 N/cm\(^2\). The pressure exerted during the implant site preparation was constantly monitored by an electronic precision balance (Excellence Plus XP, Mettler-Toledo, Giesen, Germany) controlled the operator at a range between 20N and 30 N; implant sites prepared with pressures higher than 30N were excluded. Thermal measurements were performed in a climate-controlled room (temperature 23\(^\circ C\) to 24\(^\circ C\); relative humidity 5%; absence of direct ventilation); temperature values were measured every 5 seconds. Two different drilling techniques were adopted: method A consisted of continuous drilling, and method B was a drill-stop technique between implant sites. During the preparation of the implant sites, irrigation was done with 2 saline solutions (refAmb or refFri; sodium chloride, Omnia spa, Fidenza, Italy), which had a flow rate of 50 mL/min throughout the drilling. RefAmb was physiological saline maintained in thermal equilibrium with the external environment (23.7\(^\circ C\)); refFri was physiological saline refrigerated at 6\(^\circ C\).

Four experimental groups were assessed. Group A consisted of implant sites prepared with the continuous drilling technique and saline solution refAmb; group B consisted of implant sites prepared with the intermittent drilling technique and the refAmb saline solution; Group C consisted of implant sites prepared with the continuous drilling technique and the refFri saline solution; Group D consisted of implant sites prepared with intermittent drilling technique and the refFri saline solution.
In group A, the average temperature was 29.68°C (range 27.78°C to 31.35°C; SD 1.21); in group B, the average temperature was 29.70°C (range 27.28°C to 31.81°C; SD 1.50), in group C, the average temperature was 27.13°C (range 26.59°C to 28.22°C; SD 0.55), and in group D the average temperature was 27.42°C (range 26.69°C to 31.87°C; SD 1.53).

The results are summarized in the Table. There were no statistically significant differences between group A and group B (W = 86; P value = 0.45). Statistically significant differences were found between group A and group C (W = 0; P = .0001); group B and group D (W = 45; P = .0005), and group C and group D (W = 41; P = .003).

**DISCUSSION**

Osseointegrated implants have become a viable option in patients affected by partial or total edentulism. Thus, if osseointegration does not take place, the result is biological failure and consequent implant loss. The primary intention of endosseous implant surface modifications is to modulate the implant and host tissue response and accomplish better osseointegration. To achieve a predictable osseointegration and to obtain a natural implant restoration, implant site development should be the least traumatic as possible. Tehemar tried to identify all the factors that influence the amount of heat generated when bone is drilled. In fact, as reported by Watzek et al., the successful healing of implants may be influenced by heat generations during rotary cutting. In particular, Iyer et al. showed that drilling speed can alter osseointegration as it affects bony tissue if inadequate irrigation is used. Thus, questions remain not only about the optimal design of the drill, the degree of heat generated depending on the bone density and the speed of the drill but also on the best type of irrigation.

Increased temperature during drilling has long being identified as critical to avoid a reduction in osteoclast and osteoblast activity and to preserve the surrounding tissues; moreover, it could be responsible for the deterioration of the organic component of the bone, which may cause local bone

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**TABLE**

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<tr>
<th>Implant Site</th>
<th>Physiological Solution at 23.7°C</th>
<th>Physiological Solution at 6°C</th>
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necrosis. The bone itself has a very low thermal conductivity that prevents heat dissipation during the drilling phase.\(^4\) Many parameters could influence the increase in temperature during drilling of the bone (ie, characteristics of the drill and the drilling technique as well as characteristics of the cortical bone itself). Hence, to overcome thermal changes, different drilling techniques have been developed and investigated.\(^3\) However, few studies have paid attention to the method for preparing the implant site.

The aim of the present in vitro study was to compare heat generation in the bone surrounding the apical region of the implant site during continuous drilling techniques versus intermittent drilling techniques; irrigation solutions at 2 different temperatures were used.

Both internal and external irrigation systems reduced the high heat generated from drilling of implant sites.\(^4\) Sener et al\(^9\) also demonstrated that external irrigation at room temperature is sufficient for cooling the implant site during drilling. According to the results in this in vitro study, no statistically significant difference between group A and group B (W = 86; \(P = .45\)) was found; however, statistically significant differences were found between group A and group C (W = 0; \(P = .0001\)); between group B and group D (W = 45; \(P = .0005\)), and between group C and group D (W = 41; \(P = .003\)). This experimental study showed that the average temperature was 29.68°C in group A, 29.70°C in group B, 27.13°C in group C, and 28.44°C in group D. Hence, the use of a refrigerant solution at a temperature of 6°C reduces the increase in bone temperature during the preparation of implant sites compared with the physiologically increased temperature at a temperature of 23.7°C. Moreover, no significant differences were found in the temperature variation generated by continuous and intermittent drilling techniques, except for groups C and D. The temperature increase between group C (continuous drilling techniques) and group D (intermittent drilling techniques) was of 1.31°C. However, a statistical difference of 1.31°C should not be considered clinically relevant, as it does not reduce the risk of thermonecrosis. In parallel, it was observed that the baseline temperature of the bone ribs (26.0 ± 1°C) differed from in vivo temperatures.

Use of a refrigerated solution can provide an advantage during preparation of the implant site; solutions at lower temperature are more effective in cooling the bone. However, concerning the 2 different methods (A and B), there were no statistically significant differences among the 2 strategies in influencing the increased bone temperature.

**Conclusions**

The method adopted for preparing the implant sites (continuous drilling technique versus intermittent drilling technique) does not affect the overheating of the bone. The use of irrigating solutions is recommended. Even though the temperature of the bone never reached the critical threshold of 47°C with either physiological saline, use of a refrigerated solution instead of an ambient-temperature solution is preferable. Cooler irrigating solutions can confer benefits in the preparation of the implant sites by eliminating several variables that can affect bone overheating (ie, shape of the drills, number of blades, usury).

**ABBREVIATIONS**

refAmb: physiological solution at 23.7°C.
refFri: physiological solution at 6.0°C.

**NOTE**

The authors have no commercial or financial dealings that may pose a conflict of interest or potential conflict of interest.

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