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# Intraosseous generation of heat during guided surgical drilling: an ex vivo study of the effect of the temperature of the irrigating fluid

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**Abstract**

We measured the rise in the intraosseous temperature caused by freehand drilling or drilling through a surgical guide, by comparing different temperatures of irrigation fluid (10 °C, 15 °C, and 20 °C), for every step of the drilling sequence (diameters 2.0, 2.5, 3.0, and 3.5 mm) and using a constant drilling speed of 1200 rpm. The axial load was controlled at 2.0 kg. Bovine ribs were used as test models. In the guided group we used 3-dimensional printed surgical guides and temperature was measured with a thermocouple. The significance of differences was assessed with the Kruskal-Wallis analysis of variance. Guided drilling with 10 °C irrigation yielded a significantly lower increment in temperature than the 20 °C-guided group. When compared with the 20 °C freehand group, the reduction in temperature in the 10 °C guided group was significantly more pronounced at all diameters except 3.5 mm. Finally, when the 10 °C-guided group was compared with the 15 °C groups, the temperature rise was significantly less at 2.5 and 3.0 mm than with the guided technique, and at 3.0 mm compared with the freehand technique. We suggest that the use of 10 °C pre-cooled irrigation fluid is superior to warmer fluid for keeping temperature down, and this reduces the difference between guided and freehand drilling.


*Keywords:* Irrigation fluid; Implants; Guided surgery; Drilling guide; Temperature; Bone drilling

## Introduction

Keeping bony trauma to a minimum during preparation of the bed of an implant permits optimal conditions for osseointegration, which plays a key part in primary healing and so contributes to the long term success of dental implants.[1]

Drilling of bone is a common technique used in various types of surgery, and the generation of heat and associated mechanical damage during rotary cutting can influence the process of osseointegration. Previous studies have shown that necrosis can develop when the temperature during osteotomy exceeds 47 °C. [2,3]

In recent years progress in the field of guided surgery has accelerated, and static surgical guides are now common devices.[4,5] Misir et al. found that when a guide is used during drilling the increase in temperature is greater than when the implant site is prepared conventionally.[6] In another study, the

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difference between the guided flapless and flap techniques in terms of increase in temperature did not differ significantly.[7] Two other studies have shown that the heat caused by drilling in a surgical guide stays within the safe zone.[8,9]

To overcome thermal damage irrigation is essential [10,11] and, in particular, cold irrigation fluid has been found to be superior to fluid warmed to room temperature in minimising rises.[12,13]

However, to the best of our knowledge there has been no research into the use of irrigation solutions at different temperatures together with a surgical guide. We have previously found that with a higher drilling speed (1200 rpm) the rise in temperature could be near the necrotic threshold, so we wished to know if the use of saline solutions at various temperatures during guided surgical drilling at a speed of 1200 rpm would result in smaller rises.

## Material and methods

Bovine ribs were used, because of their favourable thermophysical and anatomical characteristics. Davidson and James had already shown that bovine ribs are thermally isotropic, whilst their conductivity is identical to that of human mandible.[14]

The densities of the cortical and cancellous bone of bovine ribs have been shown to be analogous to those of human bone as measured by computed tomography,[15] and the study by Katranji et al. concluded that the mean edentulous and dentate cortical thickness falls between 1 and 2 mm, and 1.6 and 2.0 mm, respectively.[16] The thicknesses of our segments of bovine rib were within the same range. Sener et al. concluded that the increase in temperature was greater in cortical bone than in the deeper parts of the drilling cavity,[12] which has been confirmed by other studies.[17,18] Specimens of bovine rib bone with a cortical thickness similar to that of the human mandible were therefore used, and the measurements (which were made in the cortical layer of the bone) described the peak temperature during drilling.

Every specimen was taken from the same animal, and they were all stored at -10 °C in normal saline solution between the experiments, as described by Sedlin and Hirsch.[19] The animal was not killed for the experiment.

Our measurements were designed to replicate the rise in temperature during preparation of an implant site throughout a full drilling sequence (2.0, 2.5, 3.0, and 3.5 mm drilling), using a standard drilling speed (1200 rpm) and a standard quantity of external irrigation solution. The factors that were varied were whether the drilling was freehand or guided, and the temperature of the irrigating saline: 20 °C, 15 °C, or 10 °C. Each group was defined by the depth of drilling, the technique, and the temperature of the irrigant. Twenty-four groups were studied, and 20 measurements made in each group. In the groups in which guided surgery was evaluated we used a model surgical guide that had 2 × 5 guiding holes with metal sleeves (Fig. 1) and four holes for the fixing pins. Entry points for the freehand groups were marked on the surface of the specimens with the help of the surgical guide.

K-type thermocouples were used to measure temperature with a connecting measurement device (Holdpeak-885A, Holdpeak, China). The thermocouples were consistently placed into a well that had been prepared with a start drill 2.0 mm in diameter and a depth of 1.8 mm (so that we could make sure that the depth of the cavity never exceeded the cortical layer). The thermocouple was placed so that it touched the lateral bony wall of the cavity that was closest to the implant bed to be drilled and then tightly filled with bone chips derived from specimens of rib from the same animal, and the hole was thoroughly sealed with plasticine to maintain adequate insulation (Fig. 2).

Measurement cavities were positioned directly underneath the metal sleeve of the surgical guide, 1.75 mm horizontally from the 2.0 mm drilling canal, 1.5 mm from the 2.5 mm drilling canal, 1.25 mm from the 3.0 mm drilling canal, and 1.0 mm from the 3.5 mm (final) drilling canal (Fig. 2). To ensure comparable results, the measurement cavities were prepared in the same positions for the freehand groups. The precise position of the measurement cavities was calculated from a 3-dimensionally printed guide, which could be anchored with pins in the same position as the model surgical guide (Fig. 1).

A constant axial pressure was maintained throughout the procedure, and the axial load was controlled at 2.0 kg. Tehemar et al. had concluded that 2.0 kg can be considered as low hand pressure, [20] and this correlated with the observations of a recently-published systematic review by Möhlhenrich et al. which confirmed that 2.0 kg is the most extensively used axial load. [21] A bench drill (Bosch PBD 40, Bosch, Germany) with adjustable speed was used for drilling.

Before the measurements were made the specimens of bone were warmed to 37 °C in saline tanks, and we drilled only when the baseline temperature had fallen between 35 °C and 37 °C. Standard, constant, external irrigation generated by a commercially-available physiodispenser surgical unit (W&H Implantmed SI-923, W&H, Austria) was applied through a standard cannula (W&H, Austria) attached to the drilling machine and directed to the drill bit at a flow rate of 105 ml/minute. The temperature of the irrigation fluid was either 20 (1)°C (room temperature), or 15 (1) °C, or 10 (1) °C. Before each measurement the temperature of the saline solutions was checked with an infrared thermometric device (Holdpeak-320, Holdpeak, China).

The full experiment is shown in Fig. 3. Each one was made (and the full apparatus stored) in the same air-conditioned room at a temperature of 20 (1) °C. Temperature rises (peak temperature minus baseline temperature) were analysed statistically with the help of Statistica for Windows 10.0 (StatSoft, Tulsa, OK, now Dell Software Group, CA, USA). As the Shapiro-Wilk test indicated that the distributions were skewed, we used the Kruskal-Wallis analysis of variance for comparisons between groups.

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