Available online at www.sciencedirect.com
SciVerse ScienceDirect
British Journal of Oral and Maxillofacial Surgery 53 (2015) 963–967
BRITISH Journal of Oral and Maxillofacial Surgery
www.bjoms.com

External cooling efficiently controls intraosseous temperature rise caused by drilling in a drilling guide system: an in vitro study

Kristof Boa[a,*], Endre Varga Jr.[b], Gabor Pinter[a], Akos Csonka[a], Istvan Gargyan[a], Endre Varga[a]

[a] *Department of Trauma Surgery, University of Szeged, Szeged, Hungary; Semmelweis u. 6., H-6725, Szeged, Hungary*
[b] *DicomLab Kft., Szeged, Hungary, Pulz u. 46/B, H-6724, Szeged, Hungary*

Accepted 15 July 2015
Available online 3 August 2015

Abstract

The purpose of this study was to measure the rise in intraosseous temperature caused by drilling through a drilling guide system. We compared the rise in temperature generated, and the number of increases of more than 10 °C, between drills that had been cooled with saline at room temperature (25 °C) and those that had not been cooled, for every step of the drilling sequence. Cortical layers of bovine ribs were used as specimens, and they were drilled through 3-dimensional printed surgical guides. Heat was measured with an infrared thermometer. The significance of differences was assessed with either a two-sample *t* test or Welch's test, depending on the variances. The mean rises (number of times that the temperature rose above10 °C) for each group of measurements were: for the 2 mm drill, 4.8 °C (0/48) when cooled and 7.0 °C (8/48) when not cooled; with the 2.5 mm drill, 5.2 °C (1/48) when cooled and 8.5 °C (17/48) when not cooled (2 mm canal); with the 3 mm drill, 3.3 °C when cooled (0/48) and 8.5 °C (18/24) when not cooled (2.5 mm canal); and with the 3.5 mm drill, 4.8 °C when cooled (0/24) and 9.4 °C when not cooled (10/23) (3 mm canal). The temperature rose significantly less with cooling at every step of the drilling sequence ($p<0.001$). We conclude that external cooling can maintain the intraosseous temperature within the safe range while drilling through an implant guide system, whereas drilling without irrigation can lead to temperatures that exceed the acceptable limit.

Keywords: Implants; Implant site preparation; Patient-specific guide; Drilling guide; Intraosseous temperature rise; Cooling; Drilling.

Introduction

Drilling of bone is commonly required in orthopaedic, craniomaxillofacial, and neurosurgery as well as dentistry, and the frictional heat that is generated leads to a rise in the intraosseous temperature. It is widely accepted that this should be kept below 47 °C, as was established by Eriksson and Adell[1] and Eriksson et al.[2] When the temperature exceeds this figure thermal osteonecrosis can develop, which leads to the bone in the affected area being replaced by fatty tissue and compromises osseointegration of the implant.[3]

More and more evidence, including a recent prospective randomised clinical study,[4] supports the premise that the use of patient-specific drilling guides can provide improved accuracy in implant dentistry. As more soft tissue and the guide itself surround the area of drilling, concerns may arise about the conduction of heat during drilling. Misir et al. concluded that drilling with the use of a guide generates more heat than

* Corresponding author. Tel.: +0036204353329; fax: +003662545530.
E-mail addresses: boa.kristof@gmail.com (K. Boa), endrevargadmd@yahoo.com (E. Varga Jr.), pinterga@redmen.hu (G. Pinter), csonka.akos81@gmail.com (A. Csonka), istvangargyandr@gmail.com (I. Gargyan), endrevargamd@yahoo.com (E. Varga).

http://dx.doi.org/10.1016/j.bjoms.2015.07.013
0266-4356/

it is generated during conventional preparation of the site of an implant.[5] Jeong et al. investigated the use of a wood and silicone model, and concluded that there was no difference between the guided flapless and flap techniques.[6] Migliorati et al. compared standard open-flap surgery, flapless standard surgery, open-flap guided surgery, and guided flapless surgery, and concluded that while guided surgery produced higher rises in the temperature of the bone, the temperature stayed in the safe zone in the latter cases as well.[7] When they compared guided surgery with the conventional technique, dos Santos et al. found that the rise in temperature also stayed within the safe zone.[8]

As this technique develops, we think that further elucidation of the topic is of importance.

Material and Methods

We used cortical bovine rib bones for drilling as they are easily available and easy to handle, as well as having ideal thermophysical and anatomical properties. Davidson and James showed that bovine cortical bone is thermally isotropic and the value of its conductivity is likely to be similar to that of human cortical bone.[9] Yacker and Klein made computed tomographic scans of bovine bones and concluded that the cortical density is about 1400 Hounsfield units (HU), while the cortical density of typical human mandible is between 1400 and 1600 HU.[10] The thickness of the cortical bone of the human mandible was studied by Katranji et al, who found that the mean edentulous cortical thickness was between 1 and 2 mm and the dentate cortical thickness between 1.6 and 2.2 mm.[11] The thickness of our specimens of bovine rib varied between 1.5 mm and 2.7 mm, which suggests that its anatomical properties are comparable with those of human mandible. This – together with our own anatomical measurements – confirm that bovine ribs are a good experimental model.

The ribs were derived from the same animal and were treated as described by Sedlin and Hirsch.[12] The specimens were frozen to -10 °C in saline solution when not in use. Before the measurements were made the specimens were warmed to 36 (1)°C, and the baseline temperature of the bone was checked before every episode of drilling. If it was less than 35 °C the specimen was returned to the warming device.

Infrared thermographic studies by Augustin et al. showed that the rise in temperature that is generated reaches its peak in the cortical layer of the bone, [13] so we designed an experiment in which we could measure the temperature of the bone around the drilled canal just before it reaches through the cortical layer, which indicates the peak intraosseous heat.

Flat parts of the ribs were divided and cut into segments that were long enough for attachment of the surgical guide that contained 3 x 8 drilling holes. The edges were then cut from the ribs longitudinally, and the specimens cut into halves through the cancellous bony layer and parallel to the flat surface of the bone. The remaining cancellous bone was then

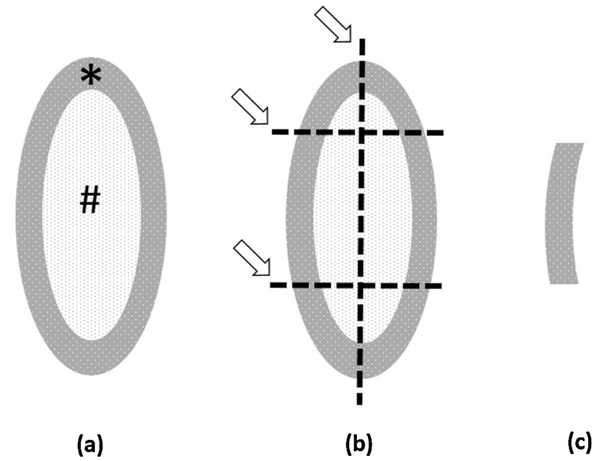

Fig. 1. Method of preparing specimens of cortical bone from bovine ribs. *=cortical layer, #=cancellous layer. White arrows and interrupted black lines indicate the directions of cutting.

removed with a chisel. We could therefore prepare quasi-flat specimens of bone that contained only the cortical layer (Fig. 1).

Heat was measured with an infrared thermometric device (Voltcraft IR-380, Conrad, Germany). The device is equipped with 2 lasers that cross each other at the focus point of the infrared measurement, which means that it is well able to be aimed at the point of exit of the drill. In the case of drilling through a preformed canal of less than 0.5 mm in diameter (as happens during the second step of the drilling sequence), the thermometer was pointed immediately next to the exit of the canal (Fig. 2).

As the specimens were flat cortical parts of bovine ribs, a universal surgical guide was designed that contained 24 guiding canals in 3 columns (Fig. 3). The guide was manufactured using the same standards as the guides of the Smart Guide system (DicomLab Kft., Szeged, Hungary), and printed 3-dimensionally (printer: ProJet 3510 MP), using the same material (VisiJet Stoneplast). The guides were anchored by placing standard pins into pinholes in each of the 4 corners.

The same experienced dentoalveolar surgeon drilled every hole to achieve as constant applied pressure as possible. Heated debris was removed from the canal with a light pumping motion. The surgeon was not able to see the screen of the thermometer (Fig. 2), so it did not affect either his usual drilling movement or the amount of pressure applied. Drill speed was set to a constant 800 rpm as advised by the manual of the Smart Guide system.

Every step of the drilling sequence was investigated, and drills of 2 mm, 2.5 mm, 3 mm, and 3.5 mm were studied.

External cooling was applied by the assistant (with a standard 50 ml syringe that contained saline solution at a room temperature of 25 °C) at the point where the drill entered the metal sleeve of the canal in the drilling guide (Fig. 2). The drills were washed and cooled to room temperature after each drilling.