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Research Paper
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Thermal evaluation by infrared measurement of implant site preparation between single and gradual drilling in artificial bone blocks of different densities

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Abstract. The aim of this study was to investigate the influence of bone density and drilling protocol on heat generation during implant bed preparation. Ten single and 10 gradual implant sites with diameters of 2.8, 3.5, and 4.2 mm were prepared in four artificial bone blocks (density types I–IV; D1–D4). Drilling was done at constant speed (1500 rpm) and with external irrigation (50 ml/min); vertical speed was set at 2 mm/s. An infrared camera was used for temperature measurements. Significantly higher temperatures for single drilling were found between 2.8-mm drills in D1 ($P = 0.0014$) and D4 ($P < 0.0001$) and between 3.5-mm drills in D3 ($P = 0.0087$) and D4 ($P < 0.0001$), as well as between 4.2-mm drills in D1 ($P < 0.0001$) and D4 ($P = 0.0014$). Low bone density led to a thermal decrease after single drilling and a thermal increase after gradual drilling. Burs with a large diameter always showed a higher temperature generation. In comparisons between 2.8- and 4.2-mm diameters for both single and gradual drills, significant differences ($P < 0.001$) were noted for bone types II, III, and IV. Single drilling could generate more heat than traditional sequential drilling, and bone density, as well as drill diameter, influenced thermal increases. Particularly in lower-density bone, conventional sequential drilling seems to raise the temperature less.

Key words: heat generation; infrared thermography; implant site preparation; dental implants; bone surgery.

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The thermal increase that occurs during implant site preparation can influence local bone. Delayed osseointegration due to bone necrosis and implant failure are the possible complications of thermal overload during implant site preparation. Studies by Eriksson and Albrektsson have demonstrated irreversible damage to the bone structure after a heat exposure of approximately 47 °C lasting 1 min. Therefore, low temperatures are necessary during osteotomy.[1–3]

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Various in vivo and in vitro studies have focused on the factors that affect and that could compromise osseointegration and lead to implant failure. Such factors include the drill speed, load applied, drilling time, drill sharpness and wear, irrigation, drill design, and the material, as well as the surgical procedure itself and the bone structure.[4] The method of irrigation is among the parameters most investigated for controlling the heat generated during implant site preparation. Cooling can be internal, external, or a combination of the two. In general, it is assumed that the highest mean temperature increase must be expected without any coolant irrigation, followed by external, internal, and combined irrigation, respectively. Internal and combined cooling have been proven to be superior to external irrigation, particularly in deep cavities.[5]

Moreover, several surgical techniques have been described in terms of their influence during implant site osteotomy. Next to the instruments for bone preparation, the surgical protocol has most often been studied. Implant bed preparation can be achieved by single or gradual drilling. Only a few studies have compared the single and sequential preparation techniques to demonstrate benefits with regard to the thermal increase in bone.[6–8] However, no optimal surgical drilling protocol has been described, and different study models have been used.

Investigations on heat generation during implant bed osteotomy have varied in the manner of temperature measurement. Two different methods for recording the real-time temperature increases have been reported: the thermocouple allows direct measurement,[9] and infrared thermography provides an indirect estimate.[10] While thermocouples detect only temperature, the infrared technique generates an overall thermal profile.

In addition, the type of bone model has varied. In vitro studies have usually used bovine or porcine bone models,[8,11–18] but synthetic foam blocks have also been described.[7,19,20] These blocks, based on polyurethane, have quality typical of oral bone, allow for good reproducibility, and are less susceptible to errors. However, the influence of the bone itself has not received much attention. Using the Misch classification,[21] the quality of the porcine and bovine bone mainly used in studies is about D3 or D4.[12,22] However, in the human maxilla and mandible, different bone structures (between D1 and D4) can be found. Therefore, these study designs must be questioned. Synthetic bone blocks with densities based on the Misch classification are available.[21] Therefore, the aim of this investigation was to evaluate the influence of the quality of four different artificial bone blocks on the heat generated during conventional multiple drilling and single drilling, as well as the influence of the drill diameter.

Materials and methods

Bone model

The implant site osteotomy was performed on four different artificial bone blocks (#1522-04, #1522-03, #1522-01, #1522-23; Sawbones, Malmö, Sweden) that have been tested in other dental implant studies.[23–28] These blocks are approved by the American Society for Testing and Materials and are recognized as a standard material for testing orthopaedic devices and instruments, making them ideal for the comparative testing of bone screws (ASTM F-1839-08). The solid rigid polyurethane foam (SRPF) blocks used in this study are classified according to density: D1, 0.48 g/cm^3; D2, 0.32 g/cm^3; D3, 0.16 g/cm^3; and D4, 0.08 g/cm^3.

Implant drill

For each test block, 10 single burs were used with surgical twist drills (Straumann, Basel, Switzerland) of 2.8 mm, 3.5 mm, and 4.2 mm in diameter, and 10 gradual implant sites were prepared with final diameters of 2.8 mm, 3.5 mm, and 4.2 mm; thus six groups were considered. A drilling depth of 12 mm was set for each diameter. The drilling speed was approximately 1500 rpm, and external irrigation was achieved with a constant 50 ml/min at room temperature (21 $\pm$ 1 °C). For the osteotomy, the blocks were fixed in a metal container, and an actuator was moved downward so that a gap of a few millimetres remained between the drill and the block (Fig. 1). From this position, the actuator was displaced vertically at a speed of 2 mm/s.

Temperature measurement

Thermal images of the drilled blocks were taken immediately after implant site preparation using a 14-bit digital infrared camera (FLIR i7; Flir Systems, Danderyd, Sweden). The parameters for acquisition were set at 320 $\times$ 240 focal plane array, 8- to 9-mm spectral range, 0.02 K noise equivalent temperature difference, 50 Hz sampling rate, optics, and germanium lens, f 20 and f/1.5. The camera was placed 0.50 m away from the test block for maximum spatial resolution. Temperature changes in the artificial bone blocks

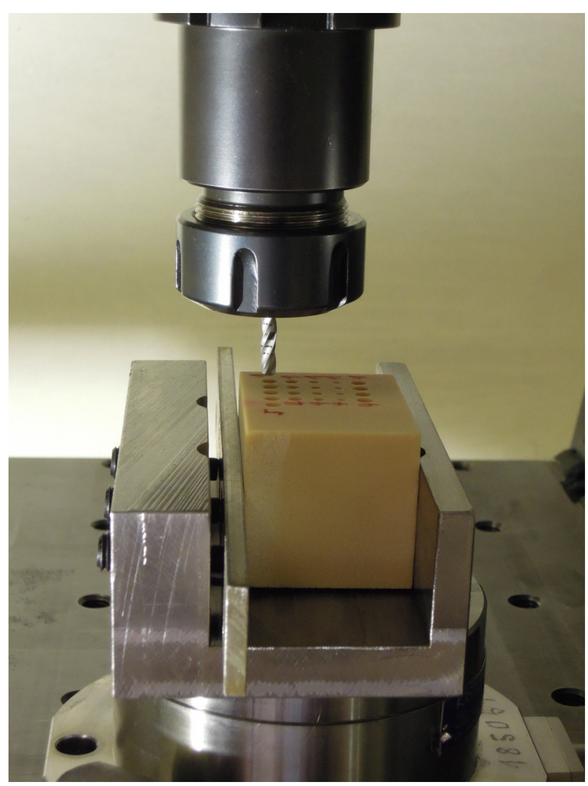

Fig. 1. SRPF blocks fixed in a metal container and the implant drill clamped in an actuator.

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