

An alternative method to record rising temperatures during dental implant site preparation: a preliminary study using bovine bone

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Summary. Overheating is constantly mentioned as a risk factor for bone necrosis that could compromise the dental implant primary stability. Uncontrolled thermal injury can result in a fibrous tissue, interpositioned at the implant-bone interface, compromising the long-term prognosis. The methods used to record temperature rise include either direct recording by thermocouple instruments or indirect estimating by infrared thermography. This preliminary study was carried out using bovine bone and a different method of temperatures rising estimation is presented. Two different types of drills were tested using fluoroptic thermometer and the effectiveness of this alternative temperature recording method was evaluated.

Key words: dental implant, heat, thermometers, bone.

Riassunto (*Metodo alternativo per la misurazione del calore generato durante la preparazione del sito implantare: studio preliminare su osso bovino*). Il surriscaldamento viene costantemente indicato come fattore di rischio per un'eventuale necrosi ossea durante la preparazione del sito implantare. Un danno da surriscaldamento può esitare nella formazione di una interfaccia fibrosa tra osso ed impianto, che compromette la prognosi a lungo termine della terapia implantare. Due metodi di registrazione sono impiegati al fine di valutare le temperature raggiunte durante la preparazione: la termocoppia (diretto) e la termografia (indiretto). Lo studio è stato condotto su osso bovino. Un diverso sistema di registrazione delle temperature è stato adottato nel presente studio, testando due differenti sistematiche di preparazione del sito implantare. L'efficacia delle metodiche di preparazione del sito implantare è stata confermata mediante l'uso di un termometro fluoroscopico.

Parole chiave: impianto, calore, termometri, osso.

INTRODUCTION

The direct bone anchorage on titanium surface, termed osseointegration, is the most important factor of dental implant success. The main surgical tenants involved in successful osseointegration are a-traumatic surgical technique and stabilization of the implant during the initial surgery [1]. Overheating is constantly mentioned as a risk factor for bone necrosis that could compromise the implant primary stability. Uncontrolled thermal injury can result in a fibrous tissue, interpositioned at the implant-bone interface, compromising the long-term prognosis [2-5]. The large amount of heat generated results from the friction of the drill with dense cortical bone [6]. Several factors have been reported to influence temperature rise during implant site preparation by drilling: drilling depth, drill flute geometry and design [7] sharpness of the cutting

tool [8, 9], variations in cortical thickness [10, 11], bone density [1, 12] drilling speed [13, 14], pressure applied to the drill [8], use of graduated versus one-step drilling [5, 15], irrigation [1, 16, 17] and equipment used (motor, contra angle, reduction power of the contra angle) [2].

From a biological point of view heat shock can induce necrosis of bone tissue [18], interruption of bone microcirculation and activation of bone marrow macrophages, and the necrotic tissues may provide conditions favourable for bacterial infection [19]. The extent of this necrotic zone varies exponentially with the magnitude of temperature reached and the duration of thermal injury [20]. Eriksson and Albrektsson stated that the threshold temperature for heat-induced injury of bone tissue is 47 °C applied for 1 minute [21, 22, 18].

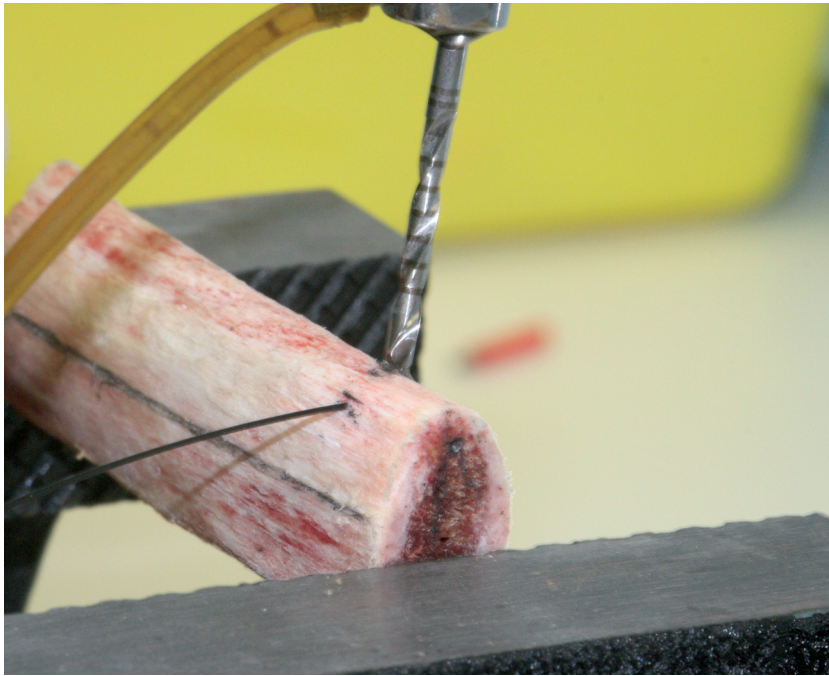


Fig. 1 | Fiber tip placed into bovine rib sample with homogeneous geometry and thickness. Initial cutting was performed with a 2 mm pilot drill.

The methods used to record temperature rise include either direct recording by thermocouple instruments or indirect estimating by infrared thermography.

In the present study a different method of temperatures rising estimation, during implant site preparation is presented. Two different types of drills were tested using fluoroptic thermometer.

MATERIALS AND METHODS

The present study was performed on adult bovine rib bone. The rib was cut into sections that measured approximately 6x1x2 cm, stripped and frozen at -10 °C. Care was taken in sample properties selection (homogeneity geometry thickness of cortical layer) (*Figure 1*).

Bone density and the relationship between cortical and cancellous bone are similar in bovine bone and in human mandibular bone [1, 5, 7].

From density analysis resulted similar Hounsfield values between human cortical and medullary bone and cortical and medullary bovine bone [1]. Hounsfield units of cortical bone in an average human mandible has been observed to be 1400 to 1600 with a medullary reading of 400 to 600 Hounsfield units.

The cortical bone in bovine ribs has been demonstrated to be 1400 Hounsfield units and the medullary bone 470 Hounsfield units.

The acquisition and recording of temperature data were performed by using a Luxtron m 3300 Biomedical Lab Kit, an optic thermometry system. The Luxtron allows users to measure temperatures where conventional sensors fail, by using probes that are totally immune to electromagnetic interference (EMI) and of entirely non-metallic construction.

These qualities make Luxtron's probes (diameter 0.5 mm) perfectly suited for measuring temperatures in harsh environments often encountered during biomedical research.

The Luxtron m3300 Biomedical Lab Kit uses patented Fluoroptic technology based on a temperature sensitive phosphorescent sensor attached to the end of the optical fiber. Pulses of light transmitted down the fiber optic probe cause the sensor to be excited. The instrument detects and calculates the decay time (τ) of fluorescence after each pulse. The decaying light signal returns through the fiber to the instrument where it is processed by converting the analogue signal into a digital value, which is then converted into a calibrated and corrected temperature. This decay time varies precisely with the temperature of the sensor, providing the basis for accurate temperature measurement. The instrument

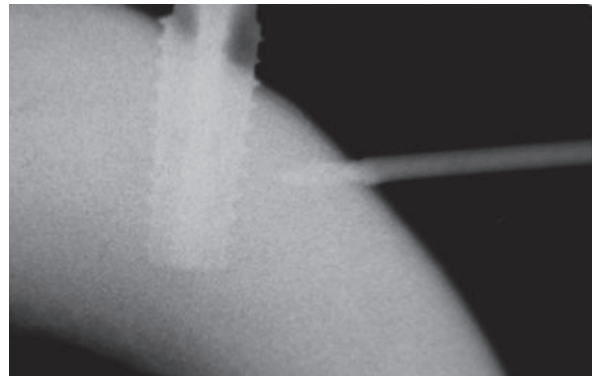


Fig. 2 | Radiograph showing a right distance between fiber probing and finishing drill for implant site preparation (0.5 mm).

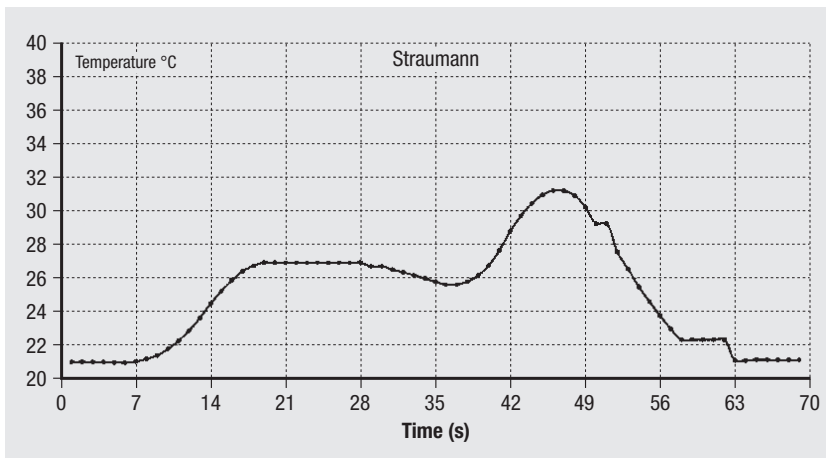


Fig. 3 | Drawing showing the temperatures rise during the first test. Temperatures recorded in one minute are represented after nine seconds of baseline values.

is capable of achieving accuracy of tenth Celsius degree over a measurement range of 0 to + 120 °C. Fluoroptic probes have a response time of 0.25 sec and data are available in real time on PC using a dedicated software. The temperature values were measured by placing the fiber tip in a horizontal canal within cortical bone. The fiber tip was situated 3 mm from the top of the sample and 0.5 mm from the boundary of drill preparation, as suggested from some authors [5-8, 10, 20, 23].

Fiber-boundary distance of 0.5 was confirmed by radiographs (*Figure 2*).

Two series of tests were conducted on two samples of bovine bone rib. Two brands of drills were tested (Straumann Italia and Camlog, Alta-Tech Biotechnologies). All osteotomies were performed by the same operator following the manufacturer's operating manual and using room temperature normal saline as coolant. The same speed rotation of 1500 rpm was maintained for all implant site preparations. Initial cutting was performed with a 2 mm drill. In the first test (Straumann Italia) the osteotomies were then enlarged with 3 mm triflute drill. In the second test (Camlog, Alta-Tech Biotechnologies) a 3.3 mm screwline drill was used.

RESULTS

Temperature data, displayed also in a real time mode, were recorded on personal computer hard disk, and after ordered and graphed using a spreadsheet. Before each trial, the baseline temperature of the bovine bone was detected and the mean value was 21 ± 0.5 °C, measured by the fiber tip of the probe, positioned in a preformed horizontal canal.

In the first test (Straumann Italia) the mean temperature value recorded with a 3 mm triflute drill was 25.7 °C; the maximum temperature value produced at the drilling site was 31.2 °C (*Figure 3*).

In the second test (Camlog, Alta-Tech Biotechnologies), the average temperature value observed during implant site preparation using a 3.3 mm screw line drill was 32.8 °C; the maximum temperature measured was 35.1 °C (*Figure 4*).

Temperature values have been recorded for 1 minute.

DISCUSSION

This study was carried out in a non-vital bovine bone samples and cannot be compared to other *in vivo* studies on heat generation during implant site preparation. There are significant differences be-

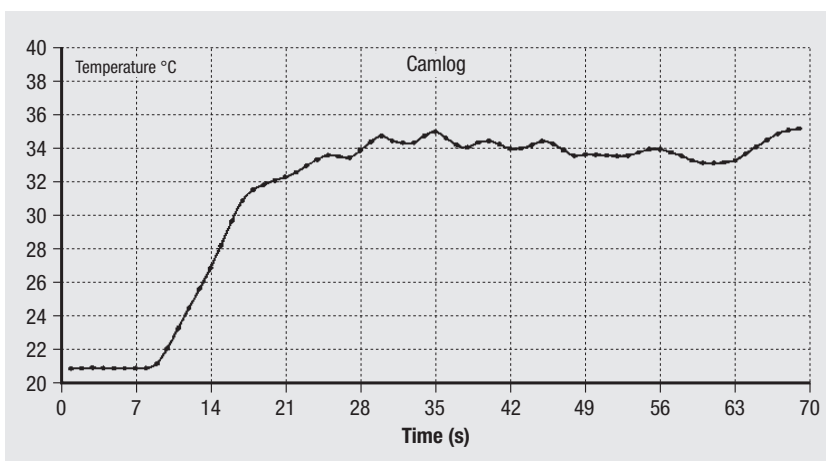


Fig. 4 | Drawing showing the temperatures rise during the second test. Temperatures recorded in one minute are represented after nine seconds of baseline values.

tween dead and living bone regarding on actual density and cellularity, water rate, fluid movement and thermal conductivity. These variables may explain the bone viability even if temperatures above threshold level have been reached. Bovine bone has been widely used by other *in vitro* studies because its density, geometry, relationship between cortical and cancellous component could be assimilated to human mandibular bone [1, 6, 8, 20, 24-30]. To retain the mechanical and thermophysical properties, the bone samples were stripped and frozen as suggested by Sedlin and Hirsch who found no significant changes in bones physical properties when it was frozen up 4 weeks [31]. The distance between probe tip and heat source represents a critical factor to obtain a proper recording temperature. Although it would be ideal to record the temperature right at the drilling site, Jochum and Reichart have shown a decrease of 2 °C changing the position of probing device from 0.3 to 0.7 mm from peripheral of the osteotomies [32]. The same temperature values were measured in a range of distance from 0.55 to 0.7 mm from the osteotomies. In our study the probe fiber was positioned in a horizontal canal drilled by using a bur of 0.8 mm of diameter at distance of 0.5 mm from the boundary surface of implant site preparation. Some methods to obtain a right distance between fiber tip and boundary of drill site were described in literature. Although a canal for probing device could be made parallel to the implant site, heat dissipation could occur along the wall of the canal with a consequent underestimation of locally temperature values. To realize vertical holes a predefined guide could be used. A finite elements method represent a possible solution to place probing fiber right the heat source. To create a finite element a removal cortical bone layer is needed. The measures so obtained are carried out within the cancellous bone, that has less density than cortical bone. The different density of the medullary component offers less resistance and reducing the heat generated could be quickly dissipated at that level, especially *in vivo* due to the presence of blood flow. To realize the horizontal holes for temperature measurement a planned drilling procedure has been considered and external reference points have been used for a right estimation of internal distances. The geometric variability of sample surface make difficult to obtain a right positioning of canal ending that represents the test point at a fixed distance from drilled vertical surface of implant site. Drilling procedures to prepare horizontal hole, as mentioned above, was driven by external reference point to maintain a distance of 0.5-1 mm. Radiographs were taken to verify the position of the tip. Implant site preparation involves the use of internal or external irrigation to reduce the heat generated. In this study an internal and external irrigation system was used without significant differences, according to other authors [20, 33]. Because of the intimate contact present at the bone drill interface, the irrigation solution has to reduce the temperature throughout the whole length of the

bony walls. The intermittent use of burs allows the escape of bone chips and access for the irrigation fluid. Whenever continuous drilling is performed, temperature will rise not only because of the inaccessibility of cooling fluid, but also because of the clogging effect of the bone debris on the cutting edge of the drill, which will decrease its cutting efficiency and consequently increase the time required for bone bed preparation [1, 4, 5, 34]. In our test series a 2 mm bur was used for the initial cutting. Temperatures recorded during their use were less high than 3 mm burs. A different distance to fiber tip may explain the similar temperatures reached with 2 and 3 mm burs. Drilling speed was kept constant at 1500 rpm, as suggested by Eriksson and Adell [5]. Different clinical and experimental studies have been conducted to evaluate the role of drilling speed, however, this issue is still being debated. Some authors have reported no significant difference in bone repair with use of different speed [4, 24, 25]. Other investigations have shown a reducing of frictional heat arising from bone drilling when low rotational speed is used [4]. In contrast Iyer stated that the rate and quality of healing are better around osteotomies prepared at high speed rather than around osteotomies performed at intermediate or low speeds [13, 14]. However different factors could contribute to such contradictory findings, such as the study models, site of drilling, type of drill use and methods of examinations. Abouzgia in his study postulated that neither the manufacturer's stated speed nor the measured free running speed could match the actual speed of the drill, as reduction in the drilling speed during cutting (up to 50%) can occur [3]. In implant practice, the evidence based recommendation of Eriksson and Adel seems to be the most applicable at the present time [5]. They have demonstrated that high-torque, low speed hand-piece running between 1500-2500 rpm are considered the ideal instruments for implant bed preparation [35].

Direct and indirect methods are commonly used to record temperature rise during drilling. Thermocouple is the direct method based on heat sensitive probe connected to thermometers or computer software. Probe isolation technique, depth of recording, material of the sensor element, error degree and other factors may influence thermocouple results; therefore, this method is under discussion. Thermocouple could record only spot temperature and seems to be inadequate to detect overall thermal profile and heat leakage [4]. Infrared thermography is a non-invasive indirect technique, based on the study of energy emitted by electromagnetic radiation. Electromagnetic radiations are emitted by all bodies and the total energy depends on the absolute temperature of the body [29]. Infrared thermography allows for a thermal picture of the drill site and surrounding tissue, and is considered more accurate than thermocouple. The cooling irrigation may represent a limit in infrared thermography use, because it could hide the temperature measurements in deeper layers of the implant site preparation [16].

As an alternative method recording temperature during drilling, a fluoroptic thermometer (Luxtron) could represent an efficient method without limits of thermocouple and infrared thermography. Luxtron probes are immune to electromagnetic and radiofrequency noise, no temperature drift or recalibration are required, are much more robust than thermocouple and are ideally suited for hostile environments. Despite thermography Luxtron could also be used with internal and external irrigation and could be used to perform a very representative estimation of real local temperature values.

CONCLUSION

The aim of the present study was to assess the feasibility of temperature recording during implant site

preparation by means of fluoroptic thermometer (Luxtron M3300). The method presented appears to be appropriate for a real-time temperature data recording as shown in this our preliminary work. Further studies are needed in order to define standardized procedures that allow a better temperature control because it could be of great support to avoid bone thermal damage during implant site preparation.

Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

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