

Thermographic analysis of burs and bone heating developed during osteotomy for dental implant placement: an *in vitro* study

Received for publication, September, 22, 2017
Accepted, December, 14, 2017

ALEXANDRU ANDREI ILIESCU¹, PAULA PERLEA^{2*}, IOANA SUCIU², SORIN DANIEL POROJAN³, LILIANA POROJAN⁴, IRINA GHEORGHIU⁵, KAMEL EARAR⁶

¹University of Medicine and Pharmacy of Craiova, Department of Oral Rehabilitation, Craiova, Romania

²University of Medicine and Pharmacy Carol Davila, Department of Endodontics, Bucharest, Romania

³University of Medicine and Pharmacy Victor Babeş, Department of Oral Rehabilitation, Timișoara, Romania

⁴University of Medicine and Pharmacy Victor Babeş, Department of Dental Prosthesis Technology, Timișoara, Romania

⁵University of Medicine and Pharmacy Carol Davila, Department of Operative Dentistry, Bucharest, Romania

⁶University Dunărea de Jos of Galați, Department of Dental Medicine, Galați, Romania

*Address for correspondence to: paula.perlea@gmail.com

Abstract

Inappropriate alveolar bone drilling during the osteotomy procedure can develop a risky local overheating. This in vitro study was conceived to investigating the simultaneous thermal changes of burs and bone tissue caused by mechanical friction while preparing the new alveolus for dental implant placement. There were drilled without cooling in bovine femoral bone a total of 30 osteotomy sites with MIS System burs at 2000 rpm, as follows: group 1 (10 osteotomies with the pilot bur of 2 mm diameter), group 2 (10 osteotomies with the bur of 2.8 mm diameter), and group 3 (10 osteotomies with the bur of 3.2 mm diameter). The thermal changes were recorded in real-time by digital infrared camera FLIR SC640 (Flir Systems). The thermographic analysis showed that the 2 mm diameter bur developed in bone a mean temperature of $46,5 \pm 0,42$, whereas the recorded bur temperature was of $64,2^{\circ}\text{C} \pm 2,58$. The bur of 2.8 mm diameter produced in bone a mean temperature of $58,2^{\circ}\text{C} \pm 1,83$ while the bur temperature arrived at $70,9^{\circ}\text{C} \pm 1,62$. Regarding the last bur, of 3.2 mm diameter, the bone mean heating was of $93,0^{\circ}\text{C} \pm 3,45$ as compared to the mean temperature of bur of $109,1^{\circ}\text{C} \pm 4,08$. Statistical analysis showed that in case of drilling with the burs of 2 mm and 2.8 mm diameter no or respectively low correlation was found between the temperatures recorded in bone and in burs. Unlike these burs, the drilling with 3.2 mm diameter bur demonstrated a higher correlation that separately allows the computation of the temperature either in bone or in drilling tool.

Keywords: bone drilling, bone heating, bur heating, infrared thermography

1. Introduction

The placement of endosseous dental implants needs to previously drill holes on alveolar ridge of upper or lower jaw. By the friction contact of the bur touching alveolar bone this surgical procedure is easy generating a local bone heating that may jeopardize the hard tissue vitality and osseointegration of dental implants, due to the risk of necrosis [1-5]. It is already documented that the unwanted bone necrosis that circumscribes the drill hole is proportional with the amount of frictional heat generated by rotational movement of the bur in the depth of bone tissue [6]. However, if the temperature is controlled by surgeon within the critical biological parameters of human body, i.e. not over passing 47°C more than 1 minute, the healing process results in the most desired implant osseointegration [7-10].

The question related to prevention of potential bone overheating during drilling, which is technically demanding, involves various parameters such as bone (thickness, histological structure, cortical or cancellous, which decides its density), drill (design, sharpness, rotational speed, depth of drilling, irrigation system), operator (pressure, modality of drilling, continue or intermittent), and patient (age, general status of health) [1].

Despite the multitude of studies dedicated to the drill geometry and irrigation systems that were used during the preparations of the implant site, too little is known if the temperatures recorded in bone are equivalent or different compared to the temperature developed in bur by frictional heating. Using the non-invasive technique of infrared thermography the present *in vitro* study aims to have an insight into this issue of particular clinical interest for high-quality osseointegration of dental implants.

2. Materials and methods

Since to date no standard model for bone heating research was accepted, as in a previous study [11] for thermographic investigations, we used hereby a version of Chacon method that aims to mimic as much as possible the bone anatomy of human jaws [12].

There were generated 3 groups of bone samples, each of them including 10 osteotomies in cortical bone with minimum thickness of 8 mm, as follows: a first group drilled with a pilot bur having 2 mm diameter, a second group using a bur of 2.8 mm diameter, and a last group by means of a bur of 3.2 mm diameter. These osteotomies were done by a single experienced dental surgeon on fresh harvested bovine femoral bone, which was previously frozen at -20°C . To avoiding dehydration each bovine bone sample was wrapped in sterile gauze soaked in saline and preserved for 2 hours at room temperature ($20 \pm 1^{\circ}\text{C}$). The drilling procedure was performed without cooling by using NSK Surgery system *Surgic XT* (Nakanishi Inc., Japan), running at 2000 rpm, and MIS System burs (MIS Implants Technologies Ltd.).

The thermal images were recorded using the digital infrared camera FLIR SC640 (Flir Systems, Sweden) with spatial resolution 0.65 mrad for 24° lens, thermal sensitivity 30 mK at 30°C , electronic zoom 1-8x, measurement accuracy $\pm 2^{\circ}\text{C}$, temperature range -40°C to -1500°C , IR resolution 640x480 pixels. Based on the infrared thermal images the temperature changes recorded in bone specimens and burs during drilling were measured in real time (Fig. 2). The experimental data were tabulated for each bur by sample, mean, and standard deviation (SD) (Table 1).

3. Results and discussion

Regardless the bur diameter (2 mm, 2.8 mm or 3.2 mm) while drilling the samples of dense cortical bone a common observation was that occurs a distinct difference of temperature between the burs and bones (Fig.1). The thermographic analysis in real-time by using digital infrared camera showed that the 2 mm diameter bur developed in bur a mean temperature of $64,2^{\circ}\text{C} \pm 2,58$ (Fig.2), whereas the recorded mean temperature in bone was of $46,5^{\circ}\text{C} \pm 0,42$ (Fig.3). The bur of 2.8 mm diameter produced in bur by drilling a mean temperature of $70,9^{\circ}\text{C} \pm 1,62$ while the bone mean temperature arrived at $58,2^{\circ}\text{C} \pm 1,83$. In case of the last bur, of 3.2 mm diameter, the bur mean heating at the completion of drilling was of $109,1^{\circ}\text{C} \pm 4,08$ but the mean temperature of bone arrived at $93,0^{\circ}\text{C} \pm 3,45$ (Fig.4).

It should be emphasized that the statistical correlation between the friction heating developed in bur and the temperature expressed by the osteotomy site (the surgical created new-alveolus for dental implant placement) has shown different ratios according to the bur diameter. The temperatures of bur and bone produced by drilling with 2 mm diameter bur are not correlated (Fig.5) as shows the too small multiple coefficient of determination (0.1875) instead of the 2.8 mm diameter bur where is evidenced a slight correlation between the thermal values expressed in bur and bone. Though the multiple coefficient of determination (0.7816) in this case it is not too high, it may be considered sufficient as $R^2 > 0.5$ (Fig.6).

In the 3.2 mm bur the correlation is somewhat stronger, the multiple coefficient of determination being of 0.8425 (Fig.7). Accordingly in this case are suggested the following calculation formulas for both thermal changes that occur during drilling, i.e. bur temperature and bone temperature:

- bur temperature = $1.08 \times \text{bone temperature} + 8.16$
- bone temperature = $0.7768 \times \text{bur temperature} + 8,3059$

Presently are used various bone models, either animal bone blocks or synthetic and resin blocks. However, it has to be highlighted that regrettably was not yet imagined a standard study model dedicated for the research in the field of implant site management, in order to achieve the standardization and reproducibility of the results [5, 13]. Hopefully recently was created an artificially bovine bone corresponding to genuine human bone type 2, according to the classification of Lekholm and Zarb [14]. This novel produced bone model is extremely promising because provides equal horizontal and vertical variables, bone density corresponding to human bone type 2, thermal conductivity analogue to human bone (0.3-0.4W/m/K), and a standardized ratio cortical/cancellous bone [15, 16].

Starting from the usual insertion of 10 and 11.5 mm dental implants in the clinical practice, the new-alveolus depth in our study respected these dimensions. Consequently on the experimental model nearby, the simulation of new-alveolus drilling was almost exclusively completed into the bovine cortical bone. Hence the thermal values were different from the anatomical clinical conditions in humans. Therefore, we cannot assimilate these maximum values in our *in vitro* study with the thermal effects of the human maxillary bones where, except for the mandibular interforaminal area well represented in the compact bone, we do not meet the bone density and thickness of the bovine femur.

To run our experiment as similar possible to anatomical and clinical status of human jaws bone it was adapted the Chacon method on fresh harvested bovine femoral bone that was frozen at -20°C . The reason of choosing bovine femoral bone for this *in vitro* study was based on thermal isotropic properties of bovine and human bones, and on homogeneity and constant thickness of bovine cortical bone as well [12]. Though the mechanical and thermal properties of bovine bone are most similar with human bone it has to be considered its higher thickness and density that results in higher drilling temperature compared to human bone [17].

The least predictable local physical parameter, but at the same time more important for the magnitude of the thermal effect than the new-alveolus depth, is bone density, which usually varies depending on vascularization from one topographic area to the other [7]. The elicited temperature during osteotomy of the bovine dense cortical bone, which has a minimal thickness of 8 mm, mimics the thermal effect produced while drilling a new-alveolus in human healthy bone. Accordingly it is definitely higher than the clinically recorded temperature in case of bone drilling in cancellous bone for immediate post-extraction placement of dental implants.

To recording in real time the bone temperature during drilling may be used two methods: thermocouples, which provide direct measurements and infrared thermography, based on indirect evaluation [12, 18]. We choused the infrared thermography in real time since is more accurate due the ability to provide uniform survey and overall thermal profile. Therefore was eliminated the shortcoming of thermocouples which detect only spot temperatures [5, 11, 19].

In our study it was shown that the bur and bone temperatures are not correlated to the 2 mm bur size and only sketched to 2.8 mm, instead of the 3.2 mm bur diameter where was found a stronger correlation. The multiple coefficient of determination even allows the suggestion of calculation formulas for the bur or bone temperature, starting from the value of the other variable. Since the thermal effect in osteotomy, according to the norms of theoretical physics, is proportional to the volume of the surgically removed bone, obviously a larger diameter bur will raise the temperature more than one of a lower size [13].

The present experimental *in vitro* model showed that the bone drilling with no breaks and additional cooling of the new-alveolus without changing the burs in the increasing sense of the diameter, as in common clinical use, generated a thermal effect directly related with the increase in

the density of the bone, which in the thick compact bone was around 93°C. The implant bed may be drilled following the one-step procedure or in gradual steps. It was found that the one-step procedure did not produce in bone a higher thermal effect compared to conventional gradual steps drilling [20]. Using the one-step procedure in our study the recorded bone temperature of drilling was in average of $46.^\circ\text{C} \pm 0.45$ in case of 2 mm diameter bur, increased then to the next bur (2.8 mm diameter) at the average of $58.2^\circ\text{C} \pm 1.93$ and at the completion of the new-alveolus drilled with 3.2 mm diameter bur reached $93.0^\circ\text{C} \pm 3.64$.

The smaller is the contact area between the bur and bone the lower is the level of bone heating [3]. The shape and design of burs control the dissipation of thermal effect during drilling [21]. Though the optimal geometry of a bur to reducing the heat during bone drilling is still a desire, it seems that conical shape is more favorable due to its smaller diameter and lateral cutting surface [3]. It is also observed a potential correlation between the bur shape and the temperature of bur head during drilling [19]. The geometry, tip angle and sharpness of the bur are strongly influencing the bone heating during osteotomy procedure [22].

In the absence of cooling during osteotomy other studies mention thermal rises above 100°C during, as in drilling the cortical femoral bone without external cooling [19]). In addition, the drilling temperature increased in a few seconds at 1°C and the thermal effect developed in bone exceeded 47°C a few millimeters from the new-alveolus wall [23]. According to another *in vitro* experiment without cooling the highest temperature was recorded at the beginning of the drilling in the superficial portion of the new-alveolus. Afterwards the values decreased progressively, so that the minimum temperature was generated in the deepest zone of the bone. The maximum recorded values were 50.9°C (3 mm), 47.4°C (7 mm) and 38.1°C (12 mm) respectively. In conclusion, the greatest thermal increase occurred at the surface of the bone and the lowest in its depth [16].

The explanation resides in both the density and implicitly the coefficient of drilling friction of the cortical compact bone superior to the cancellous bone, as well as in the longer duration of the surgical process required to drilling the dense cortical area [16, 22]. The risk of necrosis is higher in cortical than in cancellous bone since, due to the low thermal conductivity of cortical bone and the common anisotropic nature of bone tissue, the heat generated by drilling is slowly dissipated. Thus the thermal effect is maintained some time around the osteotomy site and the subsequent deleterious consequences are easy to be understood [8, 13, 22]. The response of cancellous bone to heating is more favorable because the thermal effect is quickly dissipated owing to the rich vascularisation and less dense structure of this kind of osseous tissue [9].

Although some studies showed an increase of the temperature with the depth of the osteotomy, it seems that the relationship between the depth of the drilling and the caloric effect is questionable. The cause would be the association of additional factors, such as the drilling technique or the cooling system, whose correlation is not yet elucidated experimentally [7]. Earlier it was emphasized that osteotomy, regardless of the type of cooling of the bur used in clinical setting (internal, external or combined), the irrigation should be intermittently provided in order to allow the penetration of cooling fluid in an efficient manner for removing the bone debris accumulated on the bur. In addition, it was also recommended that combined cooling has to be used to avoid the thermal effect reaching the risk limit, especially in the thick cortical bone [7]. The double irrigation system associated to bone drilling is significantly more efficient than the external irrigation technique used separately, since the supplementary internal irrigation is helpful both for cooling and diminishing the friction due to self-cleaning from bone debris [24].

Despite the obvious control of bone heating below the level considered harmful, the disputes over the efficiency of cooling systems remain open. Preliminary studies questioned the need for internal cooling since it was found that the use of external cooling results in avoiding the bone heating above the thermal biological limit accepted for alkaline phosphatase (56°C)[1]. In view of these results it can virtually be considered that internal cooling during drilling the implant bed would have no clinical advantage over the external one which is usual, simpler and cheaper. Moreover, it seems that the internal irrigation is not as beneficial as it was expected in the depth of

the osteotomy site during the implant bed preparation since the temperatures developed *in situ* above 47°C are not a rule [1, 5]. The allegation that the heating generated during bone drilling is not directly proportional to the irrigation volume might be helpful for surgery as the smaller the amount of cooling flush the better the visibility of the operational field [25].

The minimization of mechanical and thermal lesions in the neoalveolar formation also depends significantly on surgeon concern to avoiding the loading of burs with tissue debris, which logically leads to the increase of the drilling pressure [19]. Though a sensitive aspect of heat generation during bone drilling, the ratio between the manual physical pressure on the bur and its speed can be controlled if it is applied correctly. To date it is known that the risk of harmful heat effect occurs only if the pressure or speed to achieve the desired clinical efficiency is raised separately. As a rule, if working at low speeds, pressure increase should be avoided [23].

An important practical issue is that the reduction of the heat released by drilling can be achieved either by shortening the drilling time or by reducing the pressure on the bur [2]. An axial load of 5-20 N during conventional drilling in both cortical and cancellous bone has no consequences regarding local thermal effect [26]. In addition to the axial load on the bur, the torque also plays a role in the generation of bone thermal lesions [27]. Despite the external cooling, due to the reduced thermal conduction of the cortical bone, the amount of heat accumulated locally can not be rapidly dispersed and it is possible to maintain a undesirable prolonged elevation of local temperature [27].

Regarding the standardization of thermal studies it may also be cited a proposal for using during drilling except the blocks of standard artificial bone and infrared thermography in real time an axial load of 2 Kg, a speed of 1500 rpm, and irrigation [5]. By low speed drilling (50 rpm) of pig cortical bone without irrigation with 2.0 mm diameter twist drill or 3.0 mm diameter pilot drill the overheating at the tip of burs was between 1.57-2.46°C, so as finally the thermal critical point of 47°C was not achieved [28]. An opportunity to minimize the human error during implant bed preparation by drilling, including the overheating, it might be the use of robotics and navigation systems that allow the control of the thermal effect and the depth of bur penetration into the bone [29]. Further investigation would confirm this advanced and extremely attractive hypothesis for harmless clinical management of endosseous dental implants.

4. Conclusion

The drill diameter definitely influences the temperature generated in bone. During osteotomy site preparation by drilling without cooling higher temperatures were consistently observed in the bur than in the bone. Bone heating during the continuous one-step drilling with the bur of 2 mm diameter resulted in with a gradient of 18°C. In case of 2.8 mm diameter bur the gradient was of 13°C whereas the bone temperature increased with 16°C while using the bur of 3.2 mm diameter. Since it is a certain degree of correlation between the temperature of the 3.2 mm diameter bur and the drilled bone, the multiple coefficient of determination allows the suggestion of some calculation formulas for temperature, either for bur or for bone tissue at the osteotomy site.

References

1. I.C. BENINGTON, P.A. BIAGIONI, J. BRIGGS, Thermal changes observed at implant sites during internal and external irrigation. *Clin Oral Impl Res*, 13: 293-297 (2002)
2. C. ERCOLI, P.D. FUNKENBUSCH, H.J. LEE. The influence of drill wear on cutting efficiency and heat production during osteotomy preparation for dental implants: a study of drill durability. *Int J Oral Maxillofac Implants* 19: 335-349 (2004)
3. H.J. OH, U.M. WIKESJO, H.S. KANG. Effect of implant drill characteristics on heat generation in osteotomy sites: a pilot study. *Clin Oral Implant Res* 22: 722-726 (2011)
4. R.M. JOCHUM, P.A. REICHART. Influence of multiple use of Timedur® titanium cannon drills: thermal response and scanning electron microscopic findings. *Clin Oral Impl Res* 11: 139-143 (2000)
5. S.C. MÖHLHENRICH, A. MODABBER, T. STEINER. Heat generation and drill wear during dental implant site preparation: systematic review. *Br J Oral Maxillofac Surg* 53: 679-689 (2015)

6. M. WEINLAENDER. Bone growth around dental implants. *Dent Clin North Am* 35: 585-601 (1991)
7. S.H. TEHEMAR. Factors affecting heat generation during implant site preparation: a review of biologic observations and future considerations. *Int J Maxillofac Implants* 14: 127-136 (1999)
8. A.R. ERIKSSON, T. ALBREKTSSON, B. GRANE. Thermal injury to bone. A vital-microscopic description of heat effects. *Int J Oral Surg* 11: 115-122 (1982)
9. A.R. ERIKSSON, T. ALBREKTSSON. The effect of heat on bone regeneration: an experimental study in the rabbit using the bone growth chamber. *J Oral Maxillofac Surg* 42: 705-711 (1984)
10. K. YOSHIDA, K. UOSHIMA, K. ODA. Influence of heat stress to matrix on bone formation. *Clin Oral Impl Res* 20: 782-790 (2009)
11. AL.A.ILIESCU, C.M. PETCU, R. MERCUȚ. Thermal changes of bone induced during drilling for dental implants placement: an *in vitro* study. *Trans Tech Public* 376: 78-88 (2017)
12. G.E. CHACON, D.L. BOWER, P.E. LARSEN. Heat production by 3 implant drill systems after repeated drilling and sterilization. *J Oral Maxillofac Surg* 64: 265-269 (2006)
13. S. GULERIA, R. O. VAISHYA. Thermal analysis of dental drilling: a review. *Int J Res Appl Sci Eng Tech* 3: 875-879 (2015)
14. G.D. STRBAC, K. GIANNIS, E. UNGER. A novel standardized bone model for thermal evaluation of bone osteotomies with various irrigation methods. *Clin Oral Implants Res* 25: 622-631 (2014)
15. S.R. DAVIDSON, D.F. JAMES. Measurement of thermal conductivity of bovine cortical bone. *Med Eng Phys* 22: 741-747 (2000)
16. B.C. SENER, G. DERGIN, B. GURSOY. Effects of irrigation temperature on heat control *in vitro* at different drilling depth. *Clin Oral Implants Res* 20: 294-298 (2009)
17. Y. HOU, C. LI, H. MA. An experimental research on bone drilling temperature in orthopaedic surgery. *Open Mater Sci J* 9: 178-188 (2015)
18. B. D'HODET, T. NEY, H. MOHLMANN. Temperaturmessungen mit Hilfe der Infrarottechnik bei enossalen Frasungen für dentale Implantate. *Z Zahnärztl Implantol* 31: 123-130 (2015)
19. A.SCARANO, A. PIATTELLI, B. ASSENZA. Infrared thermographic evaluation of temperature modification during implant site preparation with cylindrical versus conical drills. *Clin Implant Dent Relat Res* 13: 319-323 (2011)
20. S.A. GEHRKE, R. BETTACH, S. TASCHIERI. Temperature changes in cortical bone after implant site preparation using a single bur versus multiple drilling steps: an *in vitro* investigation. *Clin Implant Dent Relat Res* 17: 700-707 (2015)
21. G. CORDIOLI, Z. MAJZOUB. Heat generation during implant site preparation: an *in vitro* study. *Int J Oral Maxillofac Implants* 12: 186-193 (1997)
22. A.G. BULUTSUZ, R.C. TANYEL, A.B. KATIBOGLU. Measurement of temperature change during the implant site preparation to determine influence of tool characteristics. *Measurement* 79: 354-359 (2016)
23. C.E. MISCH. Density of bone: effect on surgical approach and healing. In: Misch CE. Contemporary implant dentistry, 3rd ed, Mosby-Elsevier, St.Louis, 2008, pp. 645-667
24. S.A. GEHRKE, H.L. NETO, F.E.C. MARDEGAN. Investigation of the effect of movement and irrigation systems on temperature in the conventional drilling of cortical bone. *Br J Oral Maxillofac Surg* 51: 953-957 (2013)
25. A. SINDEL, O. DERECEI, M. HATIPOGLU. The effects of irrigation volume to the heat generation during implant surgery. *Med Oral Patol Oral Cir Bucal* 22: e506-511 (2017)
26. A. RASHAD, A. KAISER, N. PROCHNOW. Heat production during different ultrasonic and conventional osteotomy preparations for dental implants. *Clin Oral Implants Res* 22: 1361-1365 (2011)
27. B.J. HARRIS, S.S. KOHLES. Effects of mechanical and thermal fatigue on dental drill performance. *Int J Oral Maxillofac Implants* 16: 819-826 (2001)
28. S.J. KIM, J. YOO, Y.S. KIM. Temperature change in pig rib bone during implant site preparation by low-speed drilling. *J Appl Oral Sci* 18: 522-527 (2010)
29. R.K. PANDEY, S.S. PANDA. Drilling of bone: a comprehensive review. *J Clin Orthop Trauma* 4: 15-30 (2013)

Table 1. Thermal values (t°C) expressed in bone and bur during drilling according to the bur diameter.

Samples	2 mm bur		2.8 mm bur		3.2 mm bur	
	Bone	Bur	Bone	Bur	Bone	Bur
1.	46.8	62.7	57.2	70.0	93.0	109.6
2.	45.9	65.4	56.1	69.7	90.8	107.1
3.	46.1	60.2	57.9	71.8	96.4	108.7
4.	46.5	63.9	60.9	72.4	85.0	98.6
5.	47.0	69.8	59.3	70.9	95.3	112.4
6.	46.9	63.1	58.8	71.5	94.7	111.8
7.	46.6	62.6	61.2	73.2	97.1	114.2
8.	46.8	67.3	55.6	68.3	94.6	110.3
9.	46.7	64.5	58.7	72.7	93.6	110.7
10.	45.7	62.8	56.4	68.6	89.7	107.2
Mean t°C	46.5	64.2	58.2	70.9	93.0	109.1
SD	0.42	2.58	1.83	1.62	3.45	4.08

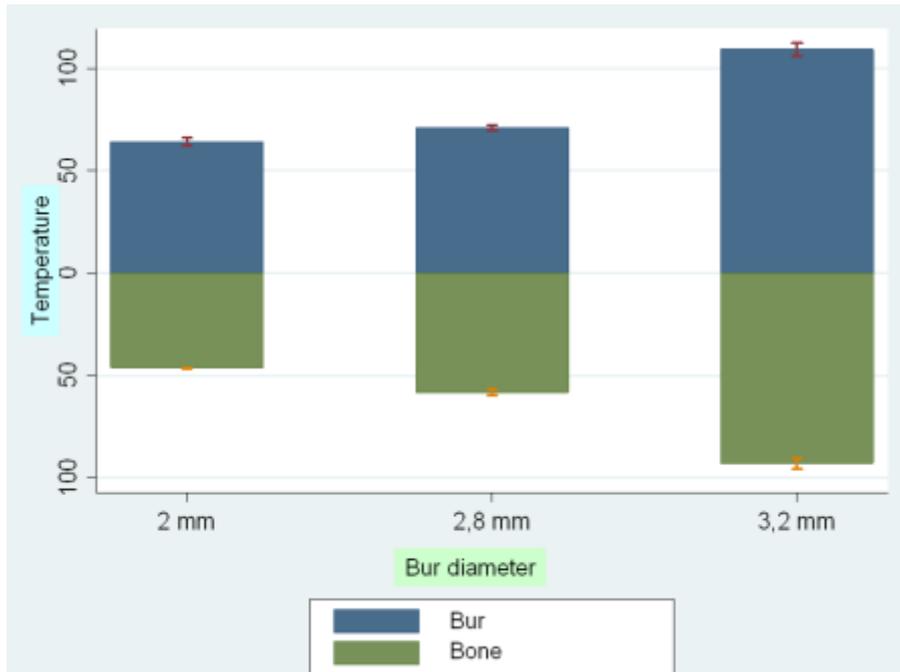


Figure 1. Heat generation during the drilling of new-alveolus in healthy bone.

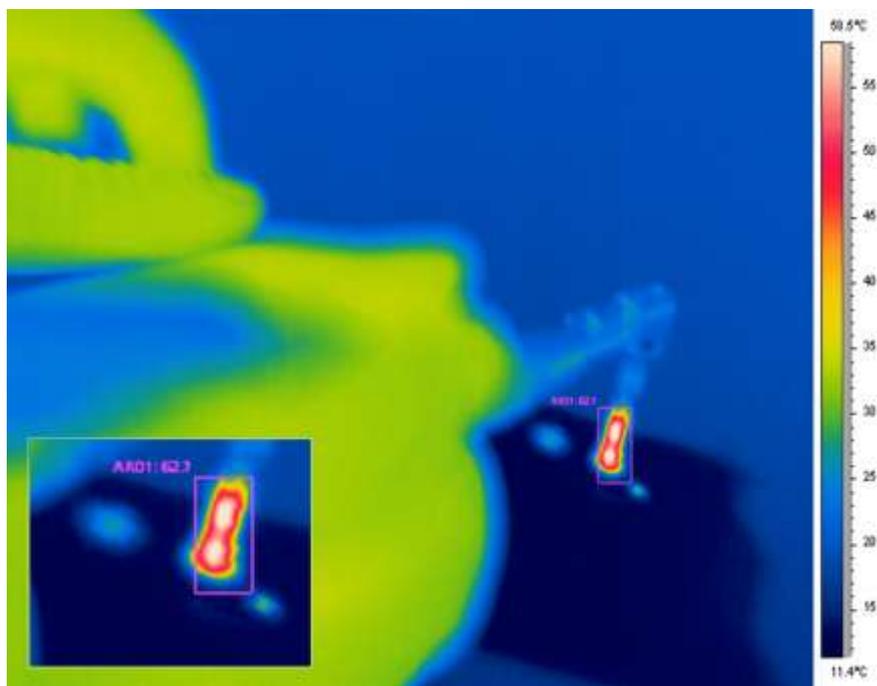


Figure 2. The bur temperature at the completion of drilling (62.7 °C).

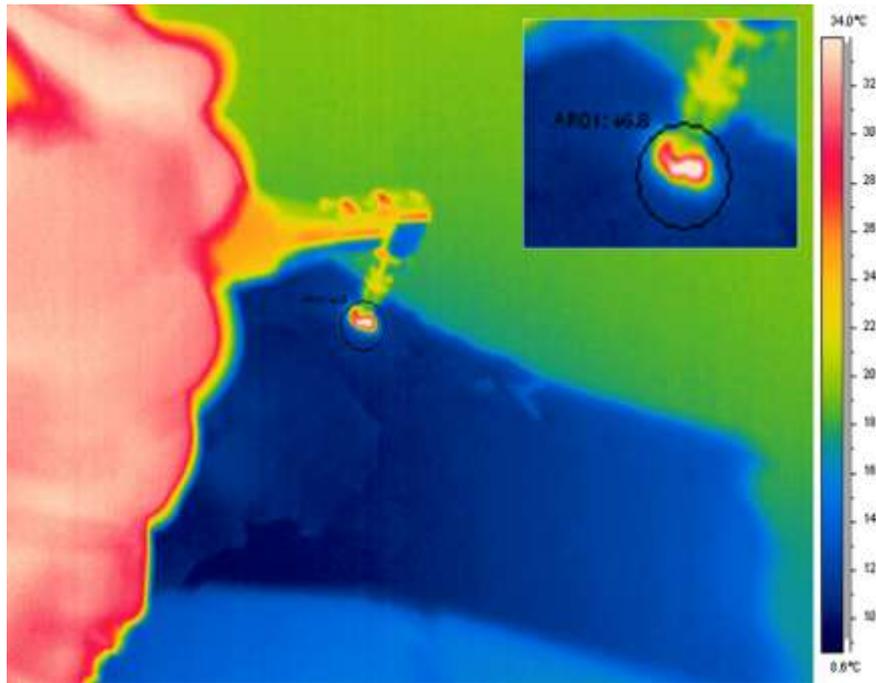


Figure 3. The bone temperature at the completion of drilling (46.8 °C).

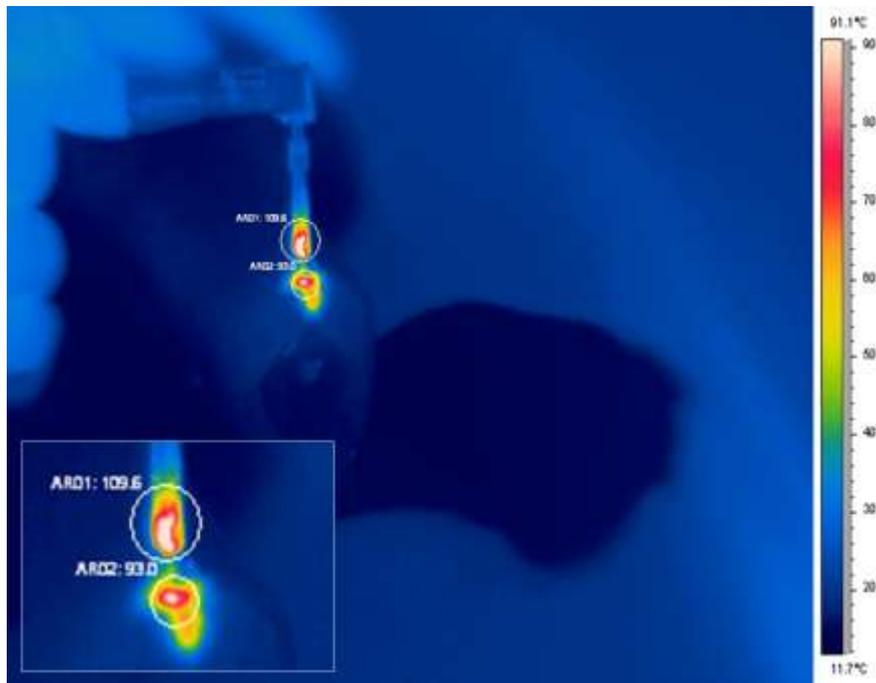


Figure 4. Extreme temperatures at the completion of drilling in bur (109.6 °C) and bone (93.0 °C).

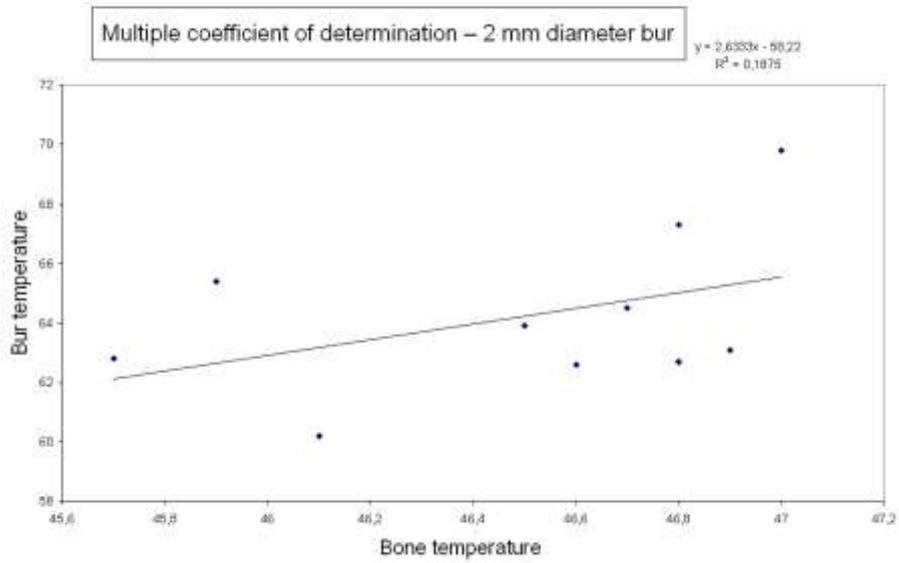


Figure 5. The temperature correlation bur/bone during drilling with 2 mm diameter bur.

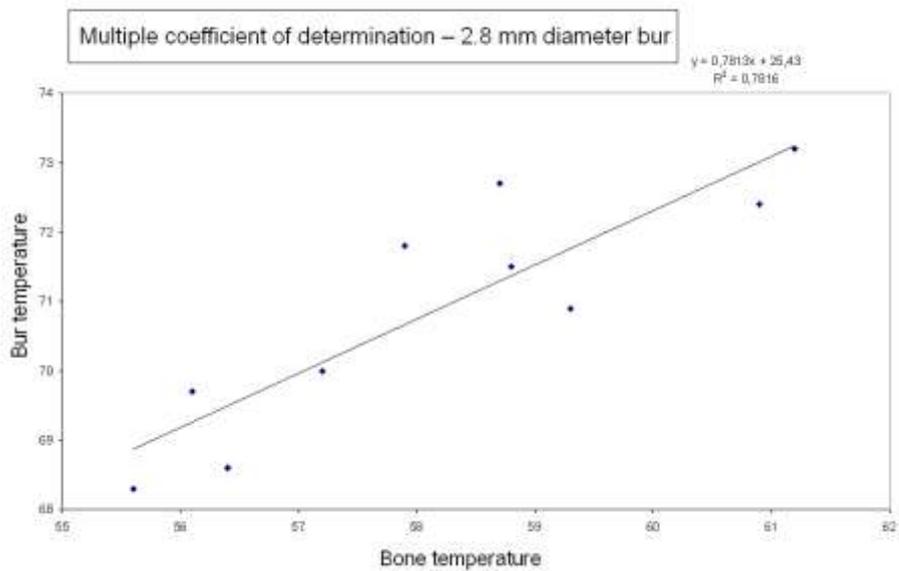


Figure 6. The temperature correlation bur/bone during drilling with 2.8 mm diameter bur.

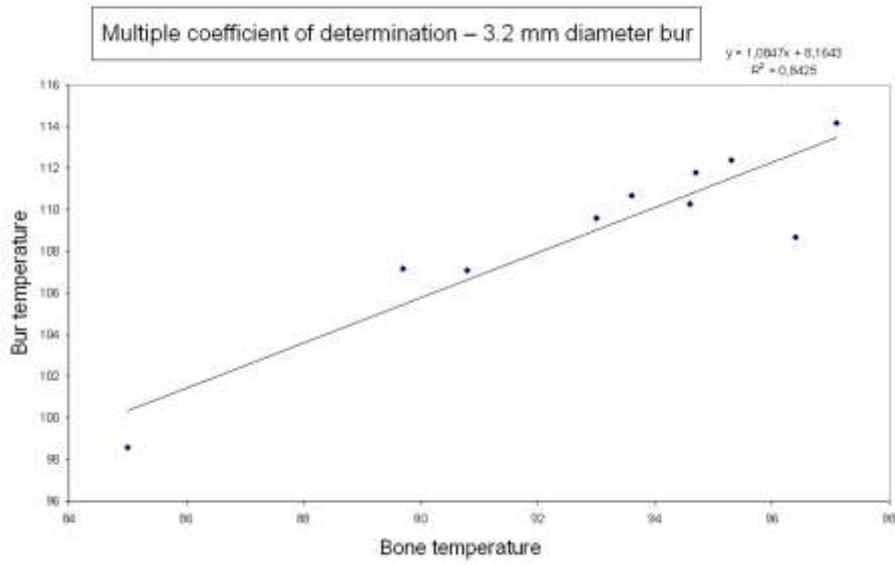


Figure 7. The temperature correlation bur/bone during drilling with 3.2 mm diameter bur.