DOI: 10.37990/medr.1249118 Med Records 2023;5(2):342-8

MEDICAL RECORDS-International Medical Journal

Research Article

Evaluation of the Temperature Values in the Use of Different Types of Burs

Mustafa Ayhan

İstanbul University, Faculty of Dentistry, Department of Oral and Maxillofacial Surgery, İstanbul, Türkiye

Abstract

Aim: In our study, we aimed to measure the amount of released head by recording it with a thermal camera during the osteotomies made utilizing round, fissure and lindemann burs to the synthetic bone blocks to simulate the mandible ramus region which is often preferred when obtaining autogenous bone from the mouth.

Material and Methods: The burs in our study were used at rotational speeds of 10000 rpm and 15000 rpm and feed rates of 60 mm/min and 90 mm/min, and each osteotomy was made with a CNC milling machine in order to standardize the applied force.

Results: According to the results of our study, the highest temperatures were observed in the fissure bur groups, and the round bur and lindemann bur groups gave similar results. In addition, when the feed rate is increased from 60 mm/min to 90 mm/min in all groups at constant rotational speed, the heat released increases significantly. When the groups are evaluated within themselves; the temperature values observed at 15000 rpm and 60 mm/min feed rate in the groups using round bur were found to be significantly lower than the group observed at 10000 rpm and 60 mm/min feed rates (p=0.028), in fissure bur groups, the temperature values observed at 10000 rpm and 60 mm/min feed rate were significantly lower than the values observed at 15000 rpm and 60 mm/min feed rates (p=0.028). No statistically significant difference was observed between the heat exchange averages of the 10000 rpm and 15000 rpm groups at a Lindemann bur 60 mm/min feed rate (p=0.182).

Conclusion: This study has shown that while the generated heat in the bone is thought to increase when the bur speeds are increased, the head generated according to bur designs can decrease and it is necessary to operate according to the characteristic features of the preferred bur.

Keywords: Burs, heat exchange, osteotomy

INTRODUCTION

Osteotomies performed using a bur are often preferred in surgical procedures such as dental implant surgery, obtaining autogenous graft and jaw fracture repair (1). Especially osteotomies are performed directly to the cortical bone during autogenous graft intake from the mouth. Usually, maxillofacial surgeons use round bur, lindemann bur and fissure bur during these autogenous graft operations. During these operations, grafts can often be taken by completely cutting the cortical layer in the bone. Bone is a structure with low thermal conductivity (2). Its low conductivity increases the bone temperature, especially in cases where fast drilling is performed or irrigation cannot reach the end of the bur (3). Osteotomy procedures involve cutting the bone and removing the debris accumulated around the bur. The bone is subjected to cutting and torque forces throughout performance of these actions, and most of the mechanical energy generated is converted into heat energy (4). The heat generated as a result of the forces must be kept below the values that will cause osteonecrosis in the bone tissue (5).

In a study by Eriksson et al., they applied 50°C heated implants to rabbit tibias and observed up to 30% bone resorption. It was reported in this study that temperatures above 47-50°C decreased the callus volume around the implant (6). Other investigations have revealed that exposing bone to 43°C for an hour, 47°C for a minute, and 55°C for 30 seconds resulted in the development of necrosis in each case (7-9).

CITATION
Ayhan M. Evalution of the Temperature Values in the Use of Different Types of Burs. Med Records. 2023;5(2):342-8. DOI:1037990/medr.1249118

Received: 08.02.2023 **Accepted:** 13.03.2023 **Published:** 23.03.2023
Corresponding Author: Mustafa Ayhan, İstanbul University, Faculty of Dentistry, Department of Oral and Maxillofacial Surgery, İstanbul, Türkiye **E-mail**: drmustafaayhan@gmail.com

Several areas of the mouth can be used to harvest autogenous bone. When selecting the donor area, the characteristics and physiology of the bone to be used, as well as the width of the area to be reconstructed, are among the factors that should be evaluated (10,11). The ascending ramus region is the most frequently chosen in maxillofacial surgery due to the donor region's breadth and the surgeon's ease of access. The ramus region is also the most cortical and bone-dense region of the mandible. Up to this date, there is no study in the literature to determine the temperatures to which the bone is exposed according to the technique and speed used while harvesting the autogenous ramus graft. In this study, we employ an infrared thermal imager to measure the heat produced on the artificial bone model at different speeds and feed rates by round, fissure, and lindemann burs, which are frequently used to obtain autogenous bone.

MATERIAL AND METHOD

In our research, we evaluated the heat produced on the bone by three distinct burs, namely the round, fissure, and lindemann burs. The rotational speeds of the burs used in the study were determined as 10000 rpm (revolutions per minute) and 15000 rpm, and the feed rates were determined as 60 mm/minute and 90 mm/minute for all burs. A standard force of 35N was applied to the bone blocks for each bur. Each osteotomy was made 20 mm long and 2 mm deep. The experiments were carried out using a CNC milling machine under constant pressure of 2 kg and at room temperature in the range of 24°C.

The technical properties of the burs, applied force and torque amounts used in our study are given in Table 1.

Table 1. The technical features of the burs employed in our study, the amount of force and torque applied

	TIP ANGLE	HELİX ANGLE	NUMBER OF CUTTERS	LATERAL CUTTING FORCE	FEED RATE	CUTTING TIP DIAMETER	DEPTH OF CUTTING	TORQUE	RPM
ROUND BUR	110-180	66	8	35 NEWTON	60MM/MIN 90MM/MIN	2MM	2MM	14-18N/MM	10K-15K
FISSURE BUR	0	60	4	35 NEWTON	60MM/MIN 90MM/MIN	2MM	2MM	18-22N/MM	10K-15K
LINDEMANN BUR	0	30	3	35 NEWTON	60MM/MIN 90MM/MIN	1.8MM	2MM	26-30N/MM	10K-15K

All burs in our study were used at two different rotational speeds and two different feed rates.

For each group, 11 osteotomies with a length of 2 cm and a depth of 2 mm were carried out, and a total of 132 osteotomies were performed. Accordingly, there are 12 groups in total. The study's groups are listed in Table 2 below.

Table 2. Groups in our study

GROUPS	BUR TYPE	ROTATIONAL SPEED	FEED RATE
GROUP1A	ROUND BUR	10000 rpm	F60
GROUP 1B	ROUND BUR	10000 rpm	F90
GROUP 2A	ROUND BUR	15000 rpm	F60
GROUP 2B	ROUND BUR	15000 rpm	F90
GROUP 3A	FİISSURE BUR	10000 rpm	F60
GROUP 3B	FİISSURE BUR	10000 rpm	F90
GROUP 4A	FİISSURE BUR	15000 rpm	F60
GROUP 4B	FİISSURE BUR	15000 rpm	F90
GROUP 5A	LINDEMANN BUR	10000 rpm	F60
GROUP 5B	LINDEMANN BUR	10000 rpm	F90
GROUP 6A	LINDEMANN BUR	15000 rpm	F60
GROUP 6B	LINDEMANN BUR	15000 rpm	F90

Standardized Synthetic Bone Blocks

In the research, universally-representative synthetic bone blocks of solid-rigid-polyurethane Sawbones (Malmo, Sweden) with dimensions of 130 mm x 180 mm x 40 mm and a density of D1 (D1=0.48 g/cc) were utilized (Figure 1). These blocks have been successfully used in different implant studies and have been approved by the American Society for Testing and Materials (ASTM). Sawbones bone blocks are recognized as a standard material for testing orthopedic devices and instruments, therefore they are also ideal for comparative testing of screws and implants inserted into the bone.

Temperature Measurement

Thermal image series were captured during the osteotomy processes utilizing a 14-bit digital infrared thermal imager (FLIR E6xt, FLIR Systems OU, Estonia). Thermal image acquisition parameters set as: 240×180 (43.200 pixels) focal plane array; 7.5–13 μm spectral range; <0.06°C (0.11°F) / <60 mK thermal sensitivity (NETD); 9 Hz display frequency; 45°×34° field of view. The camera was positioned 30 cm distant from the test block for maximum spatial resolution and FLIR MSX imaging (Multi-Spectral Dynamic Imaging). The collected pictures were utilized to measure temperature changes in artificial bone blocks during implant site preparation. The maximum temperature reached in the bone was measured during each implant osteotomy (Figure 2).

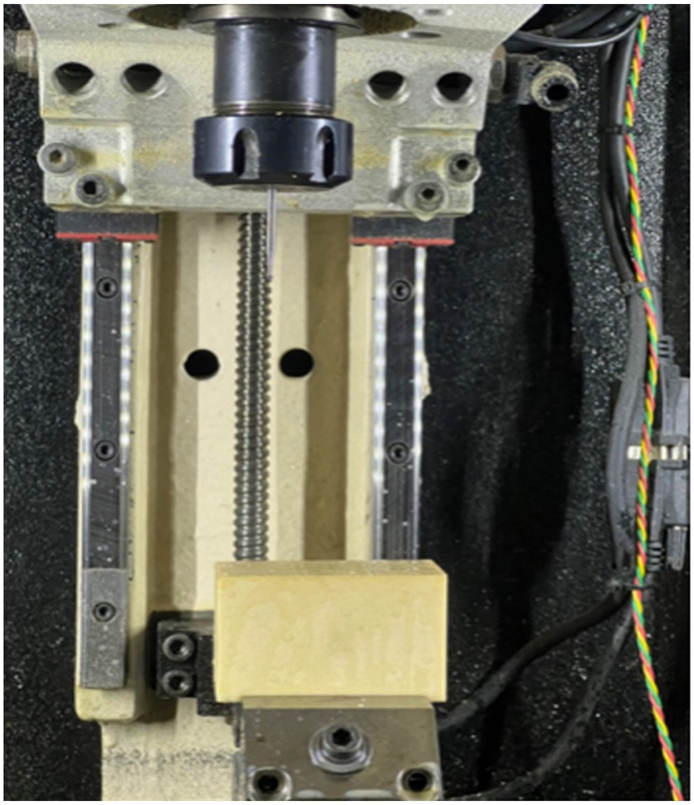

Figure 1. D1 density synthetic bone block used in our study

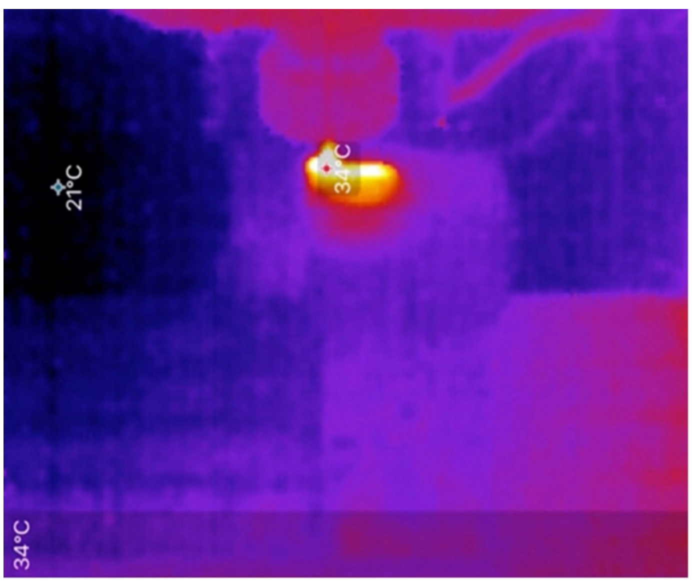

Figure 2. Digital image of infrared thermal camera

Experimental Procedure

To simulate the physical characteristics of a surgeon's osteotomy movement during the process, the application setup has been placed on a computerized numerical control milling tool (KCNM-3050, Kale CNC Istanbul, Turkey) using the parameters listed in Table 1 (Figure 3). Direct current and voltage controlled servo motors and square slide bearings were employed to prepare the experimental setup. The friction coefficients of the square slides and ball bearings were calculated to ensure that the lateral force was 35 N during machining.

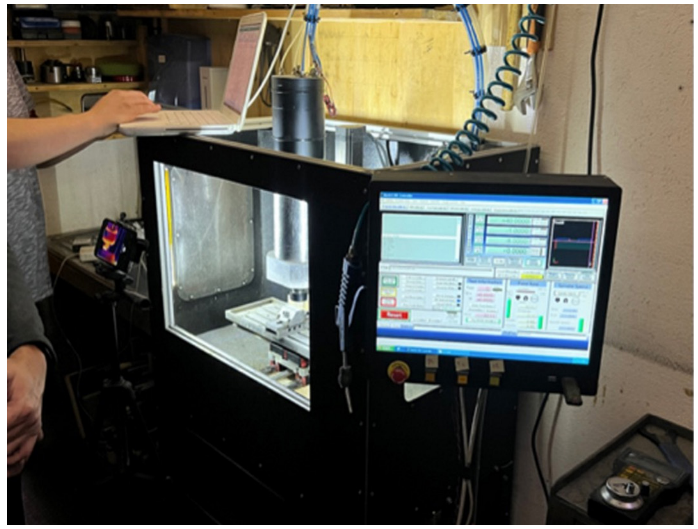

Figure 3. CNC milling machine

After the bone block had been secured to the appropriate area of the CNC milling tool, the experiment's preset tip had been attached, and the codes for the milling tool's rotational speed, feed rate, and osteotomy number had been set. All of the burs that were employed made right-angle contact with the bone blocks. In our investigation, we waited 3 seconds for the bone to return to its initial temperature between successive procedures in order to prevent the accumulated heat that will occur throughout sequential procedures.

The size of each executed osteotomy was 20 mm long and 2 mm deep. The temperature readings were instantly captured with the thermal camera, which was previously set up at a distance of 30 cm. The highest temperature value observed in each osteotomy was determined (Figure 4-5).

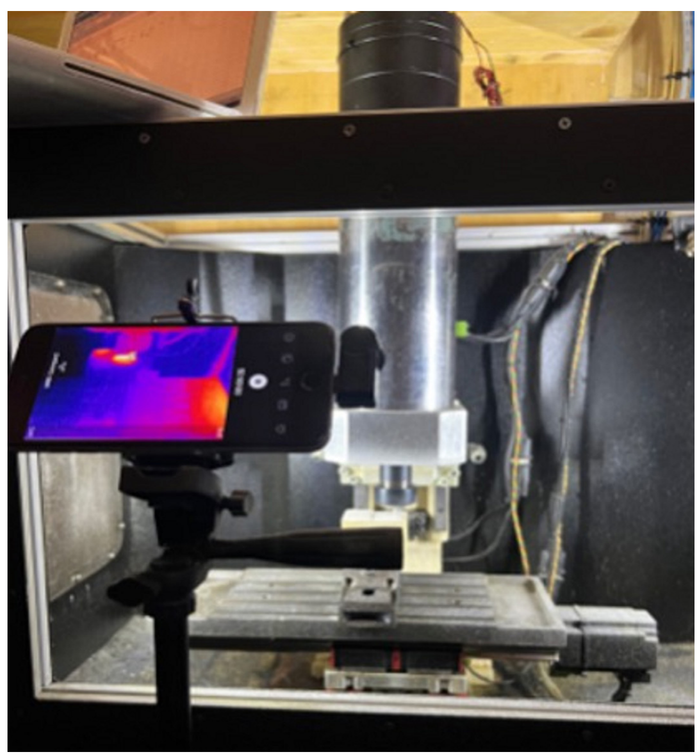

Figure 4. Thermal camera recording during cutting

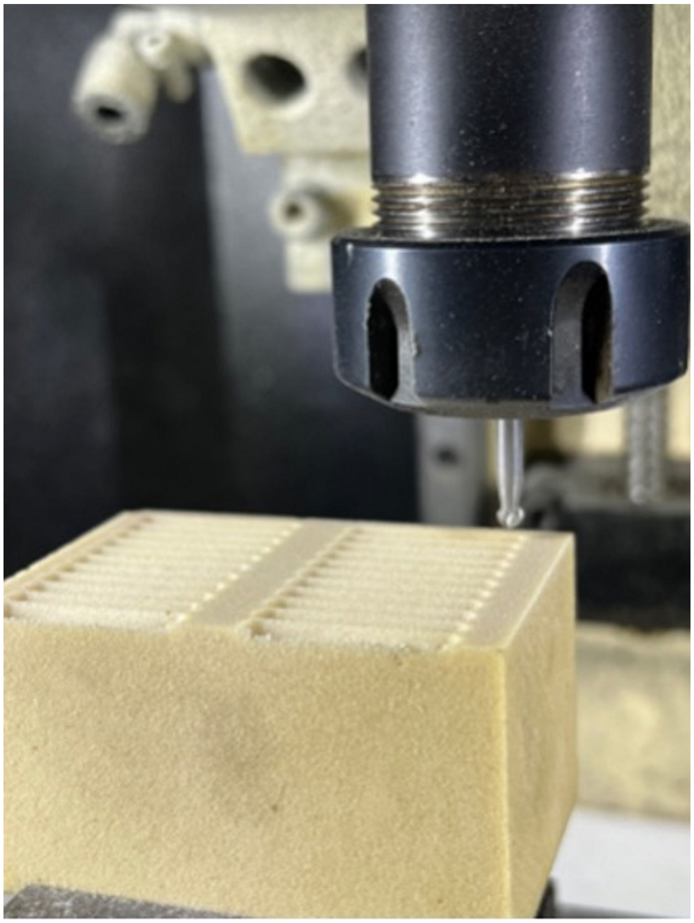

Figure 5. Image of the block after the osteotomy is completed

Statistical Analysis

The NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) package program was used to perform the statistical analyses for this study.

In the evaluation of the data, descriptive statistical methods (mean, standard deviation) as well as Shapiro–Wilk normality test and distribution of variables were examined, Three-Way ANOVA test was used for the comparisons between Bur, Rotational Speed and Feed Rate of normally distributed variables, and Tukey multiple comparison test was used for subgroup comparisons. The results were evaluated at the significance level of p<0.05.

Three-Way ANOVA				
Bur	**Rotational Speed**	**F60**	**F90**	**Total**
Ruond Bur	1000 rpm	36.00±1.34	38.73±1.10	37.36±1.84
	1500 rpm	34.27±2.01	37.55±0.69	35.91±2.22
	Total	35.14±1.89	38.14±1.08	36.64±2.15
Fissure Bur	1000 rpm	41.00±1.73	51.82±2.75	46.41±5.97
	1500 rpm	46.00±2.00	53.82±1.99	49.91±4.45
	Total	43.50±3.14	52.82±2.56	48.16±5.50
Lindemann Bur	1000 rpm	35.55±0.93	37.73±0.65	36.64±1.36
	1500 rpm	34.82±1.47	37.45±0.82	36.14±1.78
	Total	35.18±1.26	37.59±0.73	36.39±1.59
Total	1000 rpm	37.52±2.84	42.76±6.74	40.14±5.77
	1500 rpm	38.36±5.77	42.94±7.91	40.65±7.25
	Total	37.94±4.53	42.85±7.29	40.39±6.53

RESULTS

An infrared camera was utilized to assess the heat levels of the three distinct burs that were used in our investigation on the D1 bone model without irrigation at two different rotational speeds and two different feed rates and the highest temperature in each osteotomy has been recorded. A total of 132 osteotomies were made in 12 different groups in total. The raw version of the data obtained in the study is given in Table 3.

Table 3. Temperature values observed during the osteotomy

GROUPS	1	2	3	4	5	6	7	8	9	10	11
1A	33	37	38	37	36	35	36	35	36	36	37
1B	37	41	39	38	39	40	39	38	38	38	39
2A	30	38	36	35	34	34	33	35	33	35	34
2B	37	36	37	38	38	38	38	38	38	38	37
3A	44	41	40	42	41	41	39	44	39	40	40
3B	45	50	54	54	51	53	51	53	55	51	53
4A	49	46	45	45	44	44	44	46	47	46	50
4B	51	52	56	57	56	55	54	52	52	53	54
5A	38	35	35	36	36	35	35	35	35	35	36
5B	38	37	38	38	39	37	38	38	38	37	37
6A	39	35	35	35	35	34	34	34	34	34	34
6B	39	36	38	38	37	38	37	38	37	37	37

At 10000 rpm F60 Feed Rate, a statistically significant difference was observed between the mean temperature changes of Round Bur (Group 1A), Fissure Bur (Group 3A) and Lindemann Bur (Group 5A) groups (p=0.0001). The heat exchange averages of the Fissure Bur group were found to be statistically significantly higher than the temperature change averages of the Round Bur and Lindemann Bur groups (p=0.0001), and no statistically significant difference was observed between the mean temperature changes of the Round Bur and Lindemann Bur groups (p=0.721) (Table 4).

At a 10000 rpm F90 Feed Rate, there was a statistically significant difference between the mean temperature changes of the Round Bur (Group 1B), Fissure Bur (Group 3B), and Lindemann Bur (Group 5B) groups (p=0.0001). In comparison to the temperature change averages, the heat exchange averages of the Fissure Bur group were found to be statistically considerably greater than the Round Bur and Lindemann Bur groups (p=0.0001), while there was no statistically significant difference between the mean temperature changes of the Round Bur and Lindemann Bur groups (p=0.385) (Table 4).

At 15000 rpm F60 Feed Rate, there was a statistically significant difference between the mean temperature changes of the Round Bur (Group 2A), Fissure Bur (Group 4A), and Lindemann Bur (Group 6A) groups (p=0.0001). The heat exchange averages of the Fissure Bur group were found to be statistically significantly higher than the temperature change averages of the Round Bur and Lindemann Bur groups (p=0.0001), there was no statistically significant difference between the mean temperature changes of the Round Bur and Lindemann Bur groups (p=0.769) (Table 4).

At 15000 rpm F90 Feed Rate, there was a statistically significant difference between the mean temperature changes of the Round Bur (Group 2B), Fissure Bur (Group 4B), and Lindemann Bur (Group 6B) groups (p=0.0001). The heat exchange averages of the Fissure Bur group were found to be statistically significantly higher than the temperature change averages of the Round Bur and Lindemann Bur groups (p=0.0001), while there was no statistically significant difference between the mean temperature changes of the Round Bur and Lindemann Bur groups (p=0.985) (Table 4).

With Round Bur at 10000 rpm and 15000 rpm, the heat exchange averages of the F90 group were found to be statistically considerably greater than those of the F60 group (p=0.0001) (Table 4).

In the Round Bur F60 Feed Rate, the temperature change averages of the 10000 rpm group were found to be statistically significantly higher than the 15000 rpm group (p=0.028) (Table 4).

In the Round Bur F90 Feed Rate, the temperature change averages of the 10000 rpm group were found to be statistically significantly higher than the 15000 rpm group (p=0.007) (Table 4).

With Fissure Bur at 10000 rpm and 15000 rpm, the heat exchange averages of the F90 group were found to be statistically considerably greater than those of the F60 group (p=0.0001) (Table 4).

In the Fissure Bur F60 Feed Rate, the temperature change averages of the 10000 rpm group were found to be statistically significantly lower than the 15000 rpm group (p=0.028) (Table 4).

In the Fissure Bur F90 Feed Rate, there was no statistically significant difference between the mean heat exchange rates of the 10000 rpm and 1500 rpm groups (p=0.065) (Table 4).

With Lindemann Bur at 10000 rpm and 15000 rpm, the heat exchange averages of the F90 group were found to be statistically considerably greater than those of the F60 group (p=0.0001) (Table 4).

At the Lindemann Bur F60 Feed Rate, there was no statistically significant difference between the mean heat exchange rates of the 10000 rpm and 15000 rpm groups (p=0.182) (Table 4).

At the Lindemann Bur F90 Feed Rate, there was no statistically significant difference between the mean heat exchange rates of the 10000 rpm and 15000 rpm groups (p=0.397) (Table 4).

Table 4. Results of a three-way anova test

	Type III Sum of Squares	Df	Mean Square	F	p
Bur	3981.02	2	1990.51	791.88	0.0001
Rotational Speed	8.76	1	8.76	3.48	0.064
Feed Rate	795.27	1	795.27	316.38	0.0001
Bur * Rotational Speed	152.02	2	76.01	30.24	0.0001
Bur * Feed Rate	322.68	2	161.34	64.19	0.0001
Rotational Speed * Feed Rate	3.67	1	3.67	1.46	0.230
Bur * Rotational Speed * Feed Rate	22.47	2	11.24	4.47	0.013

DISCUSSION

The temperature rise in the bone during rotational system osteotomies is influenced by a number of variables. Some of these variables include the osteotomy site, specifically the amount of cortical and cancellous bone, and the potential influence of bone density. The quantity of the heat produced is directly influenced by elements including the feed rate, rotational speed, and bur geometry. Regardless of the source, this temperature rise can cause bone damage or impaired healing. As was previously stated, the acknowledged threshold for thermal damage to bone is 47°C for a duration of 1 minute (12-13).

The round, fissure, and lindemann burs, which are frequently used during the harvesting of autogenous grafts in the clinic (14), were chosen in our investigation, and unlike previous studies, osteotomies were not carried out by the surgeon. The reason for this is that the amount of force transmitted to the bone cannot be standardized in studies performed using the human hand. This is why, in our study, a CNC milling equipment that can apply constant force, feed rate, and torque in every osteotomy has been constructed, and this device has been employed while performing osteotomies, in order to resolve this issue.

There are no studies in the literature in the field of maxillofacial surgery and dentistry evaluating autogenous graft harvesting and its thermal effect without the use of irrigation. In our investigation, osteotomies were performed without irrigation in order to demonstrate how much the burs heated up regardless of irrigation. Due to physical impossibilities, irrigation sometimes does not reach the bur completely during clinical usage, and more than expected amount occurs in the bur.

In a study, temperature increases and osteotomy times were investigated in different bone materials (15). The bone model created from bovine bone is not different from human bone or other simulation models examined, and it can replicate human ribs, as shown in this study. Bovine and polyurethane-based bone models are also shown to be similar to human bone. An additional study found that polyurethane-based artificial bone blocks were very beneficial due to their repeatability and ability to simulate human bone (16). Parallel to these trials, bone blocks made of polyurethane were used in our study. We preferred to use an infrared thermal imager because it can measure heat indirectly instantaneously and its reliability has been proven scientifically. These cameras create a thermal profile of the bur area and the surrounding tissue by detecting it on the surface through a color scale and in this way, they can easily detect make temperature from a certain distance (17).

According to the data from our investigation, an increase in the feed rate raises bone temperature when the rotation rate is maintained constant in practically all groups.

The sawdust produced by the cutting edge wants to progress toward the channels that have not yet been emptied as the feed rate rises, compressing the chip that was made in the previous rotation but has not yet been discharged and releasing heat in the process. In this instance, when the feed rate rises, eventually the cutting tip will be unable to make contact with the material, and the force of the feed will result in deformation of the shaft of the bur's end. Our research indicates that while round burs and lindemann burs produce less heat than fissure burs, their use is potentially safer because the lowest temperature values in our study were observed in the groups where these burs were used at F60 feed rate and 15000 rpm. In cases where the speed is lower in round bur and lindemann bur (10000 rpm), each individual cutting tip comes into contact with the surface for a longer time depending on the cutting speed. Accordingly, the temperature values formed in the bone are higher than the groups used at 15000 rpm.

In cases where the fissure bur is used, a speed of 10000 rpm and a feed rate of F60 will be preferred, which will produce the lowest possible heat. Fissure burs release more heat than round and lindemann burs, so it's important to remember to maintain excellent irrigation while using them. The angle of the cutting tip of the fissure bur and the outermost point of the cutting tip and the tooth bottom diameter are less than other burs, which makes it difficult to remove the cutting material. The sooner the surface relationship of the removed chip and the bur is cut off, the less the heat is released due to friction. The fissure bur cannot successfully remove the sawdust without irrigation at the feed rates used in the experiment and the feed force simulating a surgeon's hand strength. This leads to heat generation.

The size and volume of chips that are ultimately removed from the surface depend on the tip geometry, the number of rotations, and the cutting speed. The volume and size of the removed sawdust should correspond to the design of the cutting tip. When this harmony is disturbed, the removed sawdust accumulates instead of being removed from the cutting surface and causes friction. Large exit gaps are very effective in removing chips (e.g., round burs), as the chip exit angles between the cutting edges increase (lindemann burs), it becomes easier to remove chips. In comparison to other burs, the fissure bur has a shorter distance between the cutting edge's tip and the tooth's bottom diameter. This causes less chips to be thrown in each round (18).

The cutting tip similarly requires a certain amount of force to lift material from the surface. When the cutting end does not have enough force due to insufficient cutting speed, rotations, or feed rate, heat is produced as the end surface rubs against the surface rather than cutting. For this reason, in general, the volume of chips removed per unit time in multi-cutting tip (round bur) or small cutting tip (lindemann bur) burs can be used at higher speed numbers than will occur with chips of very small sizes. As the diameter of the bur or cutting tip increases (fissure bur), it is also worked at lower speeds. Overly much friction and heat are generated if the working speed is lower or higher than it should be (19).

The limits of our research can be demonstrated by the absence of actual bone tissue and irrigation in any of the study groups for the reasons already mentioned. It is necessary to conduct studies utilizing actual bone in the same experimental design.

CONCLUSION

In spite of the fact that increasing bur speeds is assumed to increase the heat created in the bone, this study demonstrated that it is important to act in accordance with the distinctive qualities of the selected bur since the heat produced according to bur designs can actually decrease.

Financial disclosures: *The authors declared that this study has received no financial support.*

Conflict of Interest: *The authors declare that they have no competing interest.*

Ethical approval: *Ethics Committee approval is not required.*

REFERENCES

1. Szalma J, Lovasz BV, Vajta L, et al. The influence of the chosen in vitro bone simulation model on intraosseous temperatures and drilling times. Sci Rep. 2019;9:11817.
2. Crowninshield RD, Pope MH. The response of compact bone in tension at various strain rates. Ann Biomed Eng. 1974;2:217–25.
3. Feldmann A, Wili P, Maquer G, Zysset P. The thermal conductivity of cortical and cancellous bone. Eur Cells Mater. 2018;35:25–33.
4. Soriano J, Garay A, Aristimuno P, Arrazola PJ. Study and improvement of surgical drill bit geometry for implant site preparation. Int J Adv Manuf Technol. 2014;74:615–27.
5. Davidson SR, James DF. Measurement of thermal conductivity of bovine cortical bone. Med Eng Phys. 2000;22:741–7.
6. Eriksson AR, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: a vital-microscopic study in the rabbit. J Prosthet Dent. 1983;50:101–7.
7. Augustin G, Zigman T, Davila S, et al. Cortical bone drilling and thermal osteonecrosis. Clin Biomech Bristol Avon. 2012;27:313–25.
8. Pandey RK, Panda SS. Drilling of bone: a comprehensive review. J Clin Orthop Trauma. 2013;4:15–30.
9. Berman AT, Reid JS, Yanicko Jr DR, et al. Thermally induced bone necrosis in rabbits. Relation to implant failure in humans. Clin Orthop Relat Res. 1984;186:284–92.
10. Chiapasco M, Abati S, Romeo E, Vogel G. Clinical outcome of autogenous bone blocks or guided bone regeneration with e-PTFE membranes for the reconstruction of narrow edentulous ridges. Clin Oral Implants Res. 1999;10:278-88.
11. Saruhan N, Ertaş Ü. Atrofik alveolar kretlerin ogmentasyonunda ekstraoral otojen kemik grefti uygulamaları. Turkiye Klinikleri J Dental Sci-Special Topics. 2012;3:18-28.
12. Toksvig-Larsen S, Ryd L, Lindstrand A. On the problem of heat generation in bone cutting. Studies on the effects on liquid cooling. J Bone Joint Surg Br. 1991;3:13-5.
13. Hall PB, Landsman A, Banks AS, Dalmia L. Thermal properties of first metatarsal osteotomies. J Foot Ankle Surg. 2009;48:432-8.
14. Singh RP, Pandey PM, Behera C, Mridha AR. Effects of rotary ultrasonic bone drilling on cutting force and temperature in the human bones. Proc Inst Mech Eng H. 2020;234:829-42.
15. Augustin G, Davila S, Mihoci K, et al. Thermal osteonecrosis and bone drilling parameters revisited. Arch Orthop Trauma Surg. 2008;128:71-7.
16. Strbac GD, Giannis K, Unger E, et al. A novel standardized bone model for thermal evaluation of bone osteotomies with various irrigation methods. Clin Oral Implants Res. 2014;25:622-31.
17. Harder S, Egert C, Freitag-Wolf S, et al. Intraosseous temperature changes during implant site preparation: in vitro comparison of thermocouples and infrared thermography. Int J Oral Maxillofac Implants. 2018;33:72-8.
18. Arif R, Fromentin G, Rossi F, Marcon B. Mechanical analysis of local cutting forces and transient state when drilling of heat-resistant austenitic stainless steel. Int J Adv Manuf Technol. 2019;104:2247-58.
19. Li P, Chang Z. Accurate modeling of working normal rake angles and working inclination angles of active cutting edges and application in cutting force prediction. Micromachines. 2021;12:1207.