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Infrared thermography comparison of heat generation between simplified and conventional implant site preparation techniques.

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Original Article

Abstract

Introduction: The predictability of osseointegration depends on a non-traumatic surgical technique that maintains cell viability. It is known that during the drilling osteotomy for implant placement occurs heat generation, being able to influence osseointegration due to thermal damage. The objective of this research was to evaluate and compare the heat generated by the drills during the preparation of surgical sites for implant placement between two different techniques: simplified (Simplified Drilling, SD) and conventional, in an *in vitro* model. **Material and methods:** Fifty implant site preparations were performed in segments of bovine ribs, divided into two groups, with the respective drill sequences: control group, conventional preparation, Ø2.0mm spear drill and Ø2.15mm, Ø2.85mm, Ø3.35mm, Ø3.85mm twist drills; SD group, Ø2.15mm and Ø3.85mm twist drills. The measurement of the temperature variation generated by each drill in each group was performed by an infrared thermal camera at three points in the bovine rib segment. **Results:** The temperature variations at one and thirteen millimeters below the drilling site were, respectively, 0.51±0.64°C and 0.46±0.59°C for the control group, and 0.62±0.76°C and 0.5±0.86°C for the SD group. No statistically significant differences were found between the control and SD groups in relation to heat generation in any of the evaluated points; p=0.288 and p=0.584, respectively for analyzes one and thirteen millimeters below the drilling site. **Discussion:** The technique of implant site preparation can be simplified, using only two drills in this modality, without showing significant differences in relation to heat generation when compared to the conventional preparation technique.

Keywords: Dental implants; Osteotomy; Temperature; Harm Reduction; Surgery; Threshold Limit Values.

COMPARAÇÃO TERMOGRÁFICA INFRAVERMELHA DA GERAÇÃO DE CALOR ENTRE AS TÉCNICAS SIMPLIFICADAS E CONVENCIONAIS DE PREPARO DE SÍTIOS DE INSTALAÇÃO DE IMPLANTE

Resumo

Introdução: A previsibilidade da osseointegração depende de uma técnica cirúrgica não-traumática que mantenha a viabilidade celular. Sabe-se que durante a osteotomia do sítio de instalação de implante ocorre geração de calor, podendo influenciar na osseointegração devido dano térmico. O objetivo desta pesquisa foi avaliar e comparar o calor gerado pelas brocas durante o preparo de sítios cirúrgicos para instalação de implantes entre duas diferentes técnicas: simplificada (Simplified Drilling, SD) e convencional, num modelo *in vitro*. **Material e métodos**: Foram realizados 50 preparos de sítios de implantes em segmentos de costelas bovinas, divididos em dois grupos, com as respectivas sequências de brocas: grupo controle, preparo convencional, broca lança Ø2,0mm e brocas helicoidais de Ø2,15mm, Ø2,85mm, Ø3,35mm, e, Ø3,85mm; grupo SD, brocas helicoidais de Ø2,15mm e Ø3,85mm. A medição da variação de temperatura gerada por cada broca em cada grupo foi realizada por uma câmera termográfica infravermelha em três pontos no segmento da costela bovina. **Resultados:** As variações de temperatura a um e treze milímetros abaixo do local da perfuração foram, respectivamente, 0,51±0,64°C e 0,46±0,59°C para o grupo controle, e, 0,62±0,76°C e 0,5±0,86°C para o grupo SD. Não foram encontradas diferenças estatisticamente significativas entre os grupos controle e SD em relação à geração de calor em nenhum dos pontos avaliados; p=0,288 e p=0,584, respectivamente para as análises um e treze milímetros abaixo do local da perfuração. **Discussão:** A técnica de preparo do sítio de instalação de implantes pode ser simplificada, utilizando apenas duas brocas nesta modalidade, sem apresentar diferenças significativas em relação à geração de calor quando comparada à técnica de preparo convencional.

Palavras-chave: Implantes dentários; Osteotomia; Temperatura; Redução de Danos; Cirurgia; Valores Limite.

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INTRODUCTION

The biological phenomenon of osseointegration, discovered by Per-Ingvar Brånemark in 1954, is conceptualized as a direct, structural and functional connection between living ordered bone and the surface of a functionally loaded implant. The predictability of osseointegration after implant placement is dependent on the biocompatibility of implant material, surgery in a sterile environment, good initial implant stability, and a non-traumatic surgical technique that maintains cell viability [1].

It is known that excessive heat generation during the preparation of the surgical bed for implant placement can cause damage to the bone that makes bone repairing and, consequently, osseointegration unfeasible [2–4]. Ample irrigation of the surgical site during osteotomy for implant installation is essential to avoid heat generation [5,6]. The conventional surgical technique for implant placement site preparation is by gradually increasing the diameter of the drills used until reaching the diameter of the desired surgical site, generally using more than two drills until reaching its final diameter. The Simplified Drilling (SD) technique, is an option for site preparation for implant placement, characterized by the use of only two drills: an initial and a final one, with the diameter of the preparations chosen for that site. Among the advantages of the SD technique, we can highlight the reduction in the possibility of perforation angulation error during site preparation and a shorter surgical time [6–16].

A variable that influences the heat generation in implant dentistry is the wear of the drills due using and sterilization cycles. Wear reduces the cutting power of the drills, thus requiring greater torque, speed and load to perform the desired osteotomy, increasing heat generation [5,17]. There is no consensus between manufacturers and professionals regarding the durability of drills, number of osteotomies and/or sterilization cycles per drill, leaving the surgeon to evaluate the performance and efficiency of the drill empirically, being held hostage to the manufacturers' recommendations [18–21]. There is no evidence in the literature whether the simplification of osteotomies in implant dentistry can generate greater wear on the drills. There are also no assessments of the relationship between osteotomy simplification and drill wear. Given the lacks of scientific evidence regarding the SD technique above reported, the present study was designed with the purpose of evaluating the safety of the technique in relation to heat generation.

MATERIAL AND METHODS

Ethical approval of studies

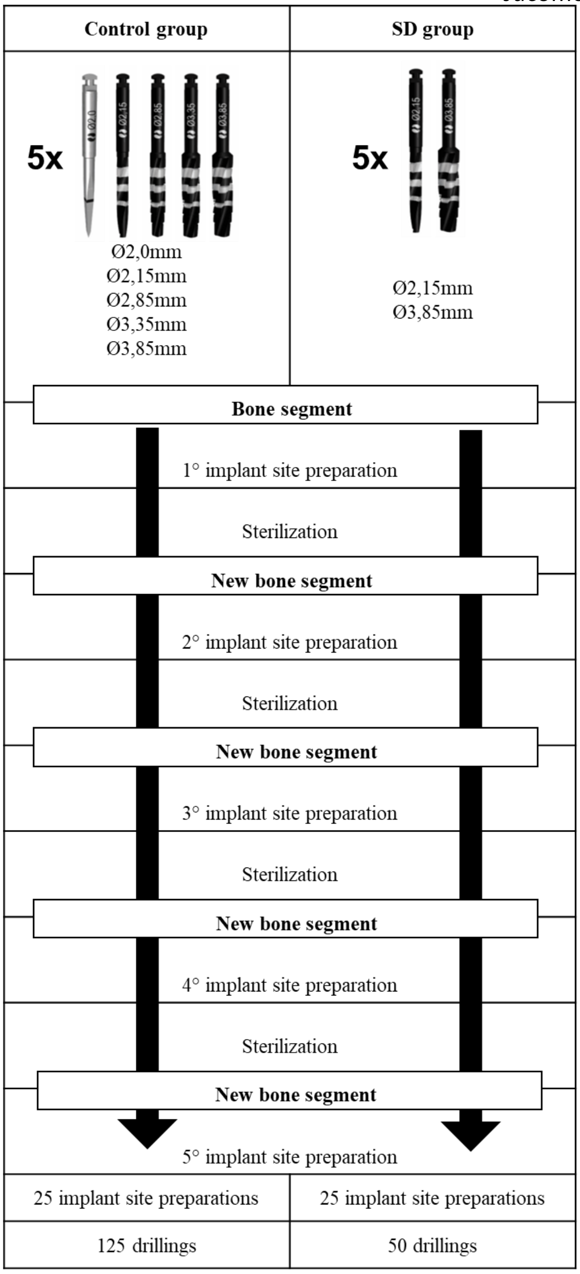
This study was submitted to the Ethics Committee in the Use of Animals of the University Santo Amaro (CEUA-UNISA), NO. 35/2021, being exempt from registration due not using live animals.

Study design

Twenty-five bone segments from the body of bovine ribs, removed from the region closest to the sternum, were acquired in a private butcher shop and prepared for this research by removing the soft tissues. These segments resemble “type 2 bone” according to the classification by Lekholm & Zarb, as they present a thick layer of compact bone covering the medullary bone with dense trabeculae.

Each bone segment was subjected to both implant placement techniques: conventional (control group) and simplified drilling (SD group), thus the same segment was drilled in two different regions, to reduce the bias caused by the possibility of bone density variations among the ribs. The sequences of drills for the implant site preparations in each group were (Figure 1):

Figure 1. Methodology flowchart.



(I) control group, conventional osteotomy, following the manufacturer's recommendations for installing cylindrical implants measuring Ø4.0mm by 13.0mm (Implant Dental Regular, Plenum, Brazil), with gradual changes in the diameter of the drills: Ø2.0mm, Ø2.15mm, Ø2.85mm, Ø3.35mm, Ø3.85mm twists;

(II) SD group, whose site preparation was made with only two drills, starting with a Ø2.15mm twist drill followed by a Ø3.85mm twist drill.

Each group contained 5 sets of each drill sequence. Each set, in each group, produced 5 implant site preparations, totaling 25 implant site preparations in each group. Between each use, the drills were undergone into a sterilization cycle (Figure 1).

Implant site preparation

To perform the drilling a support for the contra-angle was made with the purpose of standardizing the osteotomies, preventing movements and oscillations from bone segments and contra-angle itself during the drilling, and, applying a constant axial load of 2Kg in the direction of the perforation on the contra-angle. The osteotomies were performed in the craniocaudal axis of the rib bone, in its thickest region.

The drills used in this research were from brand Plenum (Jundiaí, São Paulo, Brazil). The osteotomy was performed by a surgical motor and contra-angle (20:1) brand NSK (Surgic Pro, Japan). The drillings with the spear drill were carried out to a depth of 7.0 mm and with the others twist drills ones, they were carried out until they reached a depth of 13.0 mm with constant irrigation of saline solution (flow rate 75 ml/min) in a controlled temperature environment of 20 °C, at a speed of 1600RPM and torque of 40N.

Sterilization

After each use, the drills were preserved in saline solution and undergone to sterilization cycles according to the manufacturer's recommendations: removal of all organic material with running water and a soft bristle brush, immersion in enzymatic detergent (Riozyme Eco, Rioquímica S/A., São José do Rio Preto, São Paulo, Brazil) in an ultrasonic vat (Cristófoli, Campo Mourão, Paraná, Brazil) for 5 minutes, further removal of possible residues with a soft-bristled brush, rinse with plenty of running water, visual inspection to verify if there were still residues of organic matter. If so, the entire process above was repeated. After that, the drills were dried with a soft, clean and dry cloth, organized and packed with the other drills in their sequence in sterilization papers (ADD-PAK, Amcor, Brazil), and submitted to steam sterilization in an autoclave – 128±5°C (123 to 133ºC) at 1.7±0.4Kgf/cm^2 (1.3 to 2.1Kgf/cm^2) (Autoclave Bioclave 12L, Gnatus, Ribeirão Preto, São Paulo, Brazil).

Thermography and data collect

Infrared thermography was performed by a high-resolution thermal camera, 1440 X 1080, (Flir One Pro, Flir Systems, Sweden) connected to a smartphone (Iphone 12, Apple, United States of America) (Figures 2). The camera features a temperature measurement range ranging from -20°C to 400°C, 70mK (meter per Kelvin) thermal sensitivity, 12µm thermal pixel, 8.7Hz frame rate. Software version: 4.2.0 (IOS application), developer FLIR Systems.

Figure 2. Infrared thermographic camera.

The bone thermographic measurements by this camera were punctual (3 points), with its location in the bone segment configured in a standardized way in all implant site preparations. The points followed this configuration (Figure 3):

Figure 3. Capture performed by the infrared thermographic camera, exemplifying points 1, 2 and 3.

• Point 1: on the side opposite the irrigation, away from it; ensuring segment's temperature control;

• Point 2: at the crest of the bone, one millimeter below the drilling site, capturing the bone temperature while cutting the cortical portion of the segment;

• Point 3: thirteen millimeters below the drilling site, capturing the temperature in the region of the end of the preparation, where the twist drills reached.

The measurement points were manually calibrated with the aid of a periodontal probe, being then marked on the bone surface by light-curing resin/gingival barrier of blue color (POTENZA BLOCCO, PHS do Brasil, Brazil) being well highlighted from the bone color, facilitating the calibration of the camera.

Each temperature measurement point generated three data: (I) $P1_0$, $P2_0$ and $P3_0$: initial temperature value before drilling at each point; (II) $P1_{MAX}$, $P2_{MAX}$ and $P3_{MAX}$: maximum temperature value, after the start of drilling, at each point; (III) $\Delta T_{Control}$, ΔT_{1mm} and ΔT_{13mm}: temperature variation at each point, calculated as the difference between the maximum temperature after the start of drilling and the initial temperature captured. As described in the following equation:

$$\Delta T = (P_{MAX}) - (P_0)$$

The drilling time (in seconds) for each drill to reach the planned depth was collected, since all captures by the thermographic camera were in video form. The video editing tool of the PowerPoint software (Microsoft Office Professional Plus 2016 Version for Windows, Microsoft, United States) was used to analyze each video, in a frame-by-frame analysis. These values were organized and from the sum of the drilling times by the drills in the same set and group, obtained the data of the total time of making that site preparation for implant installation according to its sequence of drills/implant site preparation technique.

Statistical analysis

To conduct the statistical analysis of the collected data, the *jamovi* software (version 1.6) [22] was used, which were explored and tested for normality (Shapiro-Wilk Test). After normality was determined, the statistical test that best suited the data was applied. The significance value adopted was 5%, $p<0.05$.

RESULTS

Drilling

The support made to standardize the implant site preparation worked without complications in all 175 drillings (125 in the control group and 50 in the SD group) in all the 50 implant site preparations performed. All drills used in this research reached the planned depth with the torque, speed and axial load applied, with no need for adjustment during the implant site preparation.

3.2 Temperature and its variations

The mean values and standard deviations of the initial and maximum temperatures at measured points by the infrared thermographic camera, from each group, are presented in Table 1. Statistically significant differences were found between all initial (P_0) and maximum (P_{MAX})

temperatures taken at the same point in both groups (*P*<0.001). However, there were perforations where the values of the initial and maximum points were the same, that is, in these cases the osteotomy was unable to generate heat, leading to temperature variation data ($\Delta T_{CONTROL}$, ΔT_{1mm} and ΔT_{13mm}) equal to zero.

Table 1. Description of the initial and maximum temperatures, after the start of drilling, in each group.

Group	Measured point	Temperature	Normality (Shapiro-Wilk)	Temperature variation	*P*-value
Control Group	$P1_0$	22.1±1.04°C	0.974 (*P*=0.016)		<0.001 a)
	$P1_{MAX}$	22.6±1.07°C	0.965 (*P*=0.003)		
	$P2_0$	22.2±1.16°C	0.956 (*P*<0.001)		<0.001 a)
	$P2_{MAX}$	22.7±0.997°C	0.877 (*P* <0.001)		
	$P3_0$	22.1±1.12°C	0.974 (*P* =0.018)		<0.001 a)
	$P3_{MAX}$	22.6±1.06°C	0.934 (*P*<0.001)		
SD Group	$P1_0$	22.1±1°C	0.963 (*P* =0.118)		<0.001 a)
	$P1_{MAX}$	22.6±1°C	0.964 (*P* =0.127)		
	$P2_0$	22.2±0.96°C	0.989 (*P* =0.915)		<0.001 a)
	$P2_{MAX}$	22.8±0.913°C	0.982 (*P* =0.626)		
	$P3_0$	22.1±1.07°C	0.964 (*P* =0.128)		<0.001 a)
	$P3_{MAX}$	22.6±0.957°C	0.976 (*P* =0.410)		

Values are presented as mean±standard deviation.

$P1_0$, $P2_0$ and $P3_0$: initial temperature value before drilling at each point; $P1_{MAX}$, $P2_{MAX}$ and $P3_{MAX}$: maximum temperature value, after the start of drilling, at each point.

[a)] Statistically significant difference compared between P_0 and P_{MAX}.

The mean initial bone temperature at control point ($P1_0$), before the start of the perforations, was 22.1±1.04°C for the control group and 22.1±1°C for the SD group, with no significant differences between the groups (*P*=0.954), ensuring that baseline bone temperature conditions were the same for both groups. The temperature variation at this point ($\Delta T_{CONTROL}$) was sometimes positive, sometimes negative; revealing that the bone adjacent to the osteotomy is influenced at distance by the heat generated by the drills and/or by the cooling provided by irrigation; this variation averaged 0.45±0.64°C. The site preparation technique for implant placement does not seem to influence this temperature variation (*P*=0.804).

The temperature variations of the groups are represented in Table 2, none variations calculated follow a normal distribution (*P*<0.001). When all osteotomies are compared, regardless of the drill and the number of sterilization and use cycles, no statistically significant differences were found between the control and SD groups in relation to temperature variation at any of the evaluated points ($\Delta T_{CONTROL}$, ΔT_{1mm} and ΔT_{13mm}).

Table 2. Description of temperature variations in each group.

Temperature variation	Control group	SD group	*P*-value
ΔT_0	0.46±0.63°C	0.43±0.67°C	0,367
ΔT_{1mm}	0.51±0.64°C	0.62±0.76°C	0.288
ΔT_{13mm}	0.46±0.59°C	0.5±0.86°C	0.584

Values are presented as mean±standard deviation.

$\Delta T_{Control}$, ΔT_{1mm} and ΔT_{13mm}: temperature variation at each point, calculated as the difference between the maximum temperature after the start of drilling (P_{MAX}) and the initial temperature captured (P_0).

Drills' influence on temperature variations

Descriptive data on temperature variations (ΔT_{1mm} and ΔT_{13mm}) per drill and preparation sequence are described in Tables 3 and 4. There were three averages of temperature variation in the SD group in the 5th osteotomy whose results were negative;

after the beginning of the perforation, the maximum temperature recorded did not exceed the initial temperature at those points, so no heat generation by the osteotomy or a high efficiency of the irrigation were found.

Table 3. Description of the temperature variation one millimeter below the drilling site (ΔT_{1mm}) in relation to the drills, cycles of sterilization and using.

Drill	Implant site preparation				
	1st	2nd	3rd	4th	5th
Control spear Ø2.0mm	1.44±1.6°C	0.66±0.41°C	0.9±0.65°C	0.58±1.65°C	1±0.62°C
Control twist Ø2.15mm	1.08±0.57°C	0.18±0.46°C	0.54±0.11°C	0.32±0.79°C	0.54±0.43°C
Control twist Ø2.85mm	0.98±0.41°C	0.1±0.26°C	0.4±0.23°C	0.08±0.4°C	0.6±0.52°C
Control twist Ø3.35mm	0.62±0.45°C	0.22±0.11°C	0.34±0.05°C	0.22±0.55°C	0.42±0.17°C
Control twist Ø3.85mm	0.38±0.43°C	0.42±0.179°C	0.22±0.16°C	0.22±0.28°C	0.36±0.3°C
SD twist Ø2.15mm	1.22±1.2°C	0.52±0.38°C	0.58±0.41°C	0.6±0.81°C	-0.06±0.27°C
SD twist Ø3.85mm	1.4±1.09°C	0.7±0.48°C	0.44±0.33°C	0.64±0.75°C	0.16±0.66°C

Values are presented as mean±standard deviation.

Table 4. Description of the temperature variation thirteen millimeter below the drilling site (ΔT_{13mm}) in relation to the drills, cycles of sterilization and using.

Drill	Implant site preparation				
	1st	2nd	3rd	4th	5th
Control spear Ø2.0mm	1.24±1.2°C	0.48±0.28°C	0.38±0.57°C	0.64±1.34°C	1.12±0.64°C
Control twist Ø2.15mm	1.1±0.8°C	0.2±0.36°C	0.26±0.31°C	0.44±0.8°C	0.66±0.31°C
Control twist Ø2.85mm	0.74±0.63°C	0.2±0.29°C	0.44±0.24°C	0.24±0.59°C	0.56±0.56°C
Control twist Ø3.35mm	0.66±0.67°C	0.18±0.22°C	0.34±0.34°C	0.2±0.41°C	0.42±0.31°C
Control twist Ø3.85mm	0.28±0.36°C	0.22±0.19°C	0.2±0.38°C	0.22±0.19°C	0.3±0.28°C
SD twist Ø2.15mm	0.32±0.16°C	0.72±1.39°C	0.38±0.36°C	0.76±1.06°C	-0.26±0.73°C
SD twist Ø3.85mm	1.34±1.13°C	0.5±0.57°C	0.44±0.21°C	0.88±0.71°C	-0.06±0.94°C

Values are presented as mean±standard deviation.

Sterilization cycles and drills using influence on temperature variations

Despite the few sterilization cycles and drills using in this research, its influence was assessed using statistical Friedman’s test. The popular ANOVA-for-repeated-measures test was not chosen and carried due to large size of samples and non-parametric data. Different associations between temperature variations and groups were performed under Friedman’s test. After, its results which shown some possible influence on temperature variations were submitted to a second statistical test, Durbin-Conover, in order to reveal where were statistical differences properly. The associations submitted to and their results by the Friedman’s test and the comparisons and their significant results by the Durbin-Conover’s test were compiled in Table 5.

Table 5. Associations and results from Friedman's and Durbin-Conover's test.

Associations submited to the Friedman's test	Friedman's *P* values	Significant pairwise comparisons between implant site preparations revealed by the Durbin-Conover's test		Durbin-Conover's *P* values
ΔT_{1mm} from all drills, from all groups	<0.001	1ST	2ND	0.001
		1ST	3RD	0.023
		1ST	4TH	<0.001
		1ST	5TH	0.004
ΔT_{13mm} from all drills, from all groups	0.049	1ST	2ND	0.004
		1ST	3RD	0.035
		1ST	4TH	0.017
ΔT_{1mm} from all drills, from control group	0.002	1ST	2ND	0.004
		1ST	4TH	<0.001
		3RD	4TH	0.022
		4TH	5TH	0.004
ΔT_{13mm} from all drills, from control group	0.022	1ST	2ND	0.019
		1ST	3RD	0.042
		1ST	4TH	0.009
		2ND	5TH	0.038
		4TH	5TH	0.019
ΔT_{1mm} from all drills, from SD group	0.009	1ST	5TH	<0.001
		2ND	5TH	0.017
		3RD	5TH	0.03
		4TH	5TH	0.03
ΔT_{13mm} from all drills, from SD group	0.030	1ST	5TH	0.003
		2ND	5TH	0.027
		2ND	5TH	0.009

The results had shown a statistically significant influence by sterilization cycles and drills using in all temperature associations tested, most of those were when the 1st or 5th implant site preparation were presented in the comparison, in both groups.

3.5 Drilling time

The average time spent by each drill, in each group, to reach the planned depth, are described in Table 6. Comparisons between the drilling times of each drill in each group were performed, revealing that there were statistical differences between the groups ($p<0.001$). The first ones drills from Control group, Ø2.0mm spear drill, did not present a statistically significant difference to the first ones from SD group, Ø2.15mm twist drill ($p=0.051$); when compared to the others, it presented a great statistical difference ($p<0.001$);

Table 6. Average time spent by each drill to reach its planned depth.

Drill	Implant site preparation				
	1st	2nd	3rd	4th	5th
Control spear Ø2.0mm	15±4.71s	11±4.69s	10.8±4.93s	12.4±4.6s	10.6±5.44s
Control twist Ø2.15mm	2.67±2.52s	2.91±3.54s	1.8±0.598s	1.83±1.04s	2.1±1.31s
Control twist Ø2.85mm	1.35±1.51s	1.67±1.69s	0.93±0.497s	0.534±0.114s	0.828±0.19s
Control twist Ø3.35mm	1.15±1.33s	0.982±0.874s	0.606±0.132s	0.446±0.115s	0.764±0.258s

Control twist Ø3.85mm	1.41±2.15s	2.02±2.29s	0.498±0.0901s	1.24±1.83s	0.602±0.152s
SD twist Ø2.15mm	2.44±0.994s	8.60±10.4s	9.30±9.45s	12.7±4.64s	2.44±0.994s
SD twist Ø3.85mm	0.956±0.270s	3.97±4.54s	5.78±4.32s	9.70±5.82s	0.956±0.270s

Values are presented as mean±standard deviation.

The Ø2.15mm twist drill in the control group only showed no statistical difference when compared to the Ø3.85mm twist drill in the SD group (p=0.998). No differences were found between the drilling time of the Ø2.15mm twist drills from the Control and SD groups (p=0.002), nor the Ø3.85mm twist drills from both groups (p<0.001).

When we consider the sum of the time spent by the drills in each group, we noticed that the control group took a significantly (p=0,01) longer time, 17,2±7,93s, to perform the implant site preparation when compared to SD group, 11,7±10,8s. The simplification of the SD group was effective in relation to the time spent to prepare the implant site.

DISCUSSION

The relationship between two different techniques for implant site preparation and the generation of heat by the drills during the osteotomies was investigated using the conducted methodology; comparing whether the simplification of preparations by reducing the number of drills used influenced the generation of heat. The results found in this study reveal that in none of the comparisons made between the temperature variations of the techniques tested, there were statistically significant differences found between the control and SD groups. Under the conditions of this research, simplifying the preparation does not seem to significantly influence the heat generation.

If, hypothetically, the temperature variations caused by the drills in this research were applied in clinical conditions, with the same speed and torque used, submitting the bone tissue at the same mean time of the perforations, there would be little or no chance of reaching the damage threshold temperature of 47°C for one minute stipulated by Eriksson et al. [3,4], confirming the safety of both preparation techniques studied regards temperature.

The temperature variation in the bone adjacent to the perforation is a relevant finding of this research. Firstly, it is worth mentioning that both groups had controlled temperature conditions for carrying out the experiments; it is possible to notice the influences of this control because we did not identify significant differences in the initial temperatures of the bone segments. The temperatures recorded at the control point, P1, were influenced both by the heat generated by the drills during drilling and by the cooling by irrigation. Thus, there is an indeterminate heat conduction through the bone tissue, which needs to be better investigated in future research.

Drillings without irrigation were not carried out to determine the influence of this factor on the research carried out. A possible bias in the methodology used is the flow of irrigation to the face of the bone segment where the temperature measurement took place. The saline packages were kept at a controlled temperature of 20°C as well as the bone segments before and throughout the experiments in order to equalize the temperature of both and reduce the possibility of influence.

With the intention of reducing the bias of the manual operation of the perforations, even if it is only one operator for the whole research, a support for the contra-angle to perform the perforations was made, immobilizing it as well as the bone segment, preventing oscillations of both. The use of supports was found in other studies [2,23,24]. In addition to the benefits of stability and uniformity of the perforations, the use of the support removed the possibility of influence of heat coming from the operator's hands to the bone segment during infrared thermographic measurement, as noted in another study [25].

Furthermore, in relation to the configuration of the perforations, the axial load of 2Kg for the perforations was chosen based on a recommendation present in the systematic review carried out by Möhlhenrich et al. [5]. There is no well-known methodology in *in vitro* research in implant dentistry with the exact load needed to perform the perforations.

It is difficult to compare studies on the production of heat by drills in implant dentistry during the preparation of sites for implant placement due to the various variables present in the methodologies of the studies: methods and measurement points, drill systems, operative techniques, drilling object, axial loads, drilling speed and so on [2,5,26]. No other research was found in the literature that compares heat generation by SD and conventional techniques using infrared thermography as a measurement method, making this research unprecedented.

In addition to the main objective, the experiments and statistical tests carried out bring data regarding the temperature variation between the drills used in each group, without revealing statistically significant differences. That is, the generation of heat between each drilling, each use of drill, as well as the preparation of the preparation as a whole, from the drilling sequence itself, do not show differences between the groups studied. The influence of each drill on the heat generation in the preparations was not evident from the data collected.

In order to bring more similarity to clinical practice, the drills were subjected to multiple cycles of sterilization and use. The temperature variation, in both groups of preparation technique, was influenced in a statistically significant way by these factors in all associations submitted to statistical tests, raising the hypothesis that the methodology performed may have caused wear on the drills. To confirm this hypothesis, further studies are needed regarding the longevity and wear of the drills [27]. Despite the need for these tests, evidence was found that repeated use of drills raises bone temperature, but not to a critical level, close to the thermal damage threshold of 47°C for one minute [18,28,29].

The simplification of the surgical site preparation technique significantly reduced the time spent to perform it when compared to the control group. The increase in heat generated in implant dentistry is directly proportional to the duration of the osteotomy/drilling [30], that is, the shorter the duration of the drilling, the fewer drills used, the more simplified a preparation is, the less temperature it will generate. We associated this benefit, of shorter surgical time, with a lower risk of infection in the postoperative period, due to less bone exposure.

The Ø2.0mm spear drill in the control group and the Ø2.15mm twist drill in the SD group, responsible for performing the osteotomy that breaks the cortical bone for the following drills, need more attention in future research and daily practice due to the statistical difference found in comparisons with other drills in relation to the time spent to perform the perforations, thus being able to suffer greater wear than the other drills, bringing greater heat generation.

The “conventional” technique for making sites for implant placement is characterized by the gradual increase in the diameter of the osteotomy through the use of several drills, but there is no standard for the proportion of increase in diameter of each drill followed by all system manufacturers. of implants. Not questioning and investigating the manufacturers' recommendations and protocols, being held hostage to the instructions for use, can prevent scientific advances in implantology.

Thus, further studies evaluating the correlation between simplified preparation techniques, heat generation and wear by use and sterilization cycles are recommended, for the construction of scientific evidence that expands and produces new surgical possibilities in implantology. The data generated by this research suggest that the site preparation technique for implant placement can be simplified, using only two drills in this modality, without showing significant differences in terms of heat generation when compared to the conventional preparation technique. The data generated by this research suggest that the site preparation technique for implant placement can be simplified, using only two drills in this modality, without showing significant differences in terms of heat generation when compared to the conventional preparation technique.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

1. Albrektsson T, Brånemark PI, Hansson HA, Lindström J. Osseointegrated titanium implants. Requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. Acta Orthop Scand. 1981;52(2):155–70.

2. Raj R, Manju V, Kumar-Gopal V, Eswar M. Analysis of factors determining thermal changes at osteotomy site in dental implant placement - An in-vitro study. J Clin Exp Dent. 2021;13(3):e234–9.

3. Eriksson RA, Albrektsson T, Magnusson B. Assessment of bone viability after heat trauma. A histological, histochemical and vital microscopic study in the rabbit. Scand J Plast Reconstr Surg. 1984;18(3):261–8.

4. Eriksson RA, Albrektsson T. The effect of heat on bone regeneration: an experimental study in the rabbit using the bone growth chamber. J Oral Maxillofac Surg Off J Am Assoc Oral Maxillofac Surg. 1984;42(11):705–11.

5. Möhlhenrich SC, Modabber A, Steiner T, Mitchell DA, Hölzle F. Heat generation and drill wear during dental implant site preparation: systematic review. Br J Oral Maxillofac Surg. 2015;53(8):679–89.

6. Wang M, Wang WR, Li MW, Chang XF, He LL. Clinical trial of simplified drilling method for dental implant site preparation. Chin J Stomatol. 2018;53(6):404–7.

7. Kim HM, Cho J-Y, Ryu J. Evaluation of implant stability using different implant drilling sequences. J Dent Sci. 2019;14(2):152–6.

8. Sarendranath A, Khan R, Tovar N, Marin C, Yoo D, Redisch J, et al. Effect of low speed drilling on osseointegration using simplified drilling procedures. Br J Oral Maxillofac Surg. 2015;53(6):550–6.

9. Giro G, Tovar N, Marin C, Bonfante EA, Jimbo R, Suzuki M, et al. The effect of simplifying dental implant drilling sequence on osseointegration: an experimental study in dogs. Int J Biomater. 2013;2013:230310.

10. Jimbo R, Giro G, Marin C, Granato R, Suzuki M, Tovar N, et al. Simplified drilling technique does not decrease dental implant osseointegration: a preliminary report. J Periodontol. 2013;84(11):1599–605.

11. El-Kholey KE, Ramasamy S, Kumar R S, Elkomy A. Effect of Simplifying Drilling Technique on Heat Generation During Osteotomy Preparation for Dental Implant. Implant Dent. 2017;26(6):888–91.

12. El-Kholey KE, Elkomy A. Effect of the Drilling Technique on Heat Generation During Osteotomy Preparation for Wide-Diameter Implants. Implant Dent. 2016;25(6):825–8.

13. Calvo-Guirado JL, Delgado-Peña J, Maté-Sánchez JE, Mareque Bueno J, Delgado-Ruiz RA, Romanos GE. Novel hybrid drilling protocol: evaluation for the implant healing--thermal changes, crestal bone loss, and bone-to-implant contact. Clin Oral Implants Res. 2015;26(7):753–60.

14. Gil LF, Sarendranath A, Neiva R, Marão HF, Tovar N, Bonfante EA, et al. Bone Healing Around Dental Implants: Simplified vs Conventional Drilling Protocols at Speed of 400 rpm. Int J Oral Maxillofac Implants. 2017;32(2):329–36.

15. Jimbo R, Janal MN, Marin C, Giro G, Tovar N, Coelho PG. The effect of implant diameter on osseointegration utilizing simplified drilling protocols. Clin Oral Implants Res. 2014;25(11):1295–300.

16. Marheineke N, Scherer U, Rücker M, von See C, Rahlf B, Gellrich N-C, et al. Evaluation of accuracy in implant site preparation performed in single- or multi-step drilling procedures. Clin Oral Investig. 2018;22(5):2057–67.

17. Scarano A, Carinci F, Quaranta A, Di Iorio D, Assenza B, Piattelli A. Effects of Bur Wear during Implant Site Preparation: An in Vitro Study. Int J Immunopathol Pharmacol. 2007;20(1_suppl):23–6.

18. Allsobrook OFL, Leichter J, Holborrow D, Swain M. Descriptive study of the longevity of dental implant surgery drills. Clin Implant Dent Relat Res. 2011;13(3):244–54.

19. Chacon GE, Bower DL, Larsen PE, McGlumphy EA, Beck FM. Heat production by 3 implant drill systems after repeated drilling and sterilization. J Oral Maxillofac Surg Off J Am Assoc Oral Maxillofac Surg. 2006;64(2):265–9.

20. Alevizakos V, Mitov G, Ahrens AM, von See C. The Influence of Implant Site Preparation and Sterilization on the Performance and Wear of Implant Drills. Int J Oral Maxillofac Implants. 2021;36(3):546–52.

21. Ercoli C, Funkenbusch PD, Lee H-J, Moss ME, Graser GN. 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. 2004;19(3):335–49.

22. jamovi [Internet]. 2021. (The jamovi project). Available from: https://www.jamovi.org

23. Oh HJ, Wikesjö UM, Kang H-S, Ku Y, Eom T-G, Koo K-T. Effect of implant drill characteristics on heat generation in osteotomy sites: a pilot study. Clin Oral Implants Res. 2011;22(7):722–6.

24. Kim S-J, Yoo J, Kim Y-S, Shin S-W. Temperature change in pig rib bone during implant site preparation by low-speed drilling. J Appl Oral Sci Rev FOB. 2010;18(5):522–7.

25. Scarano A, Piattelli A, Assenza B, Carinci F, Di Donato L, Romani GL, et al. Infrared thermographic evaluation of temperature modifications induced during implant site preparation with cylindrical versus conical drills. Clin Implant Dent Relat Res. 2011;13(4):319–23.

26. Kniha K, Heussen N, Weber E, Möhlhenrich SC, Hölzle F, Modabber A. Temperature Threshold Values of Bone Necrosis for Thermo-Explantation of Dental Implants—A Systematic Review on Preclinical In Vivo Research. Materials. 2020;13(16):3461.

27. Bernabeu-Mira JC, Pellicer-Chover H, Peñarrocha-Diago M, Peñarrocha-Oltra D. In Vitro Study on Bone Heating during Drilling of the Implant Site: Material, Design and Wear of the Surgical Drill. Materials. 2020;13(8):1921.

28. Oliveira N, Alaejos-Algarra F, Mareque-Bueno J, Ferrés-Padró E, Hernández-Alfaro F. Thermal changes and drill wear in bovine bone during implant site preparation. A comparative in vitro study: twisted stainless steel and ceramic drills. Clin Oral Implants Res. 2012;23(8):963–9.

29. Koo K-T, Kim M-H, Kim H-Y, Wikesjö UME, Yang J-H, Yeo I-S. Effects of Implant Drill Wear, Irrigation, and Drill Materials on Heat Generation in Osteotomy Sites. J Oral Implantol. 2015;41(2):e19–23.

30. Cordioli G, Majzoub Z. Heat generation during implant site preparation: an in vitro study. Int J Oral Maxillofac Implants.1997;12(2):186–93.