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Systematic investigation to the influence of temperature, angulation and speed on the temperature change at the bone - Effects of the piezodriven periosteal dissection-

Freya Kastl, Sebastian Kühl, Gergo Mitov, Marcus Stoetzer, Constantin von See

Abstract— **Background: In the application of piezo-controlled periosteal dissection, it is important that it does not lead to overheating and therefore to a thermal deterioration of the tissue.**

Purpose: In this study, the temperature development will be studied in the piezocontrolled periosteum dissection in two different angles and with different force.

Materials and Methods: The tested corresponding tip for the preparation was the piezoelectric raspatory PR 1. The hand piece of the piezosurgery device was clamped on a motor driven slide. The measurement of the temperature was taken with an infrared thermometer. For the investigations cattle ridges were used at room temperate with a forwar-speed of six centimeters per minute. The hand piece was clamped in different angulations and rotations combined with five different pressures. Each of the rotation combinations were carried out with five different pressures. A special gripper was used to examine the pressure on the bone samples.

Results: At no point of the measurement, a temperature was measured greater than 33 ° C.

Conclusion: The present study could show that under in vitro conditions the use of a new piezo derived raspatorium for periosteal preparation generated temperatures far below the critical temperature for bone necrosis.

Clinical Relevance: The application of the piezodriven periosteal elevation leads to no temperature rise in the bone.

Index Terms— **piezocontrolled, forwar-speed, vitro.**

I. INTRODUCTION

Piezosurgery proves to be an established technique for dental surgery [1]. Based upon the physical effect of piezoelectricity, it was invented in 1988 and commercially launched in 2002 [1, 2]

The characteristic feature of piezoelectric systems is selective bone cutting and preservation of soft tissue. This is realized since mineralized tissues are altered by frequencies above 30 kHz while soft tissue damage occurs by frequencies over 50 kHz [1, 3, 4-6]. Several studies approved Piezosurgery as a less traumatic method for dental surgeries, such as maxillary sinus augmentation, osteotomies and crest bone expansion [3, 4, 7-9]. Compared to conventional drilling, ultrasonic implant site preparation shows a significantly higher heat generation, however till now without serious consequences in studies under in vivo conditions in terms of necrosis [1, 10, 11].

Heat is defined as the potential, the mechanical energy of atoms and free electrons, which is directly depending on the applicated power [12]. Water rinse and irrigation is thus recommended to avoid bone overheating during surgery. Heat reactions in bone such as inflammation or necrosis are temperature dependent. A temperature of 47°C is regarded as a threshold for serious bone damage due to deproteinization [11, 13, 14].

Lamazza examined possible influences of piezoelectric devices on temperature and proved correlations between heat appearance and pressure during implant site preparation [15]. Several studies confirm the effect of pressure on the temperature, underlining the indispensability of cooling irrigation [5, 14, 16]. The success of surgical treatment does not only depend on atraumatic techniques in the hard tissue management, moreover careful subperiostal preparation maintaining periosteal microcirculation is crucial in oral surgery [6]. The outstanding effect of the periosteum on bone remodelling is confirmed [17, 18], but conventional raspatories might mechanically damage the soft tissues and thus negatively affect the microcirculation and regenerative potential [6]. Therefore a new piezoelectric device for periosteal elevation was invented and the first histological study in animal studies showed a significantly higher microcirculation in the periosteum and better wound healing eight days after muoperiosteal flap preparation [6]. The piezodriven subperiosteal elevator has a micromovement of the working tip of 21-24 kHz. In animal investigation this showed that collective cutting of the periosteum in subperiosteal preparation is feasible and the mechanical trauma is significantly reduced when compared to conventional techniques [6]. These results give a new perspective on subperiostal preparation, but also demands for basic research on heat development. The present study was conducted to evaluate the temperature development of a special ultrasonic raspatory device for periosteal preparation with piezo technology

Freya Kastl, Gergo Mitov and Constantin von See, Here Department Danube Private University; Steiner Landstraße 124; 3500 Krems; Austria; www.DP-Uni.ac.at; Tel: 0042676842419368

Sebastian Kühl, His Department Klinik für Zahnärztliche Chirurgie, -Radiologie, Mund- und Kieferheilkunde, Hebelstrasse 3; 4056 Basel; Tel: 0041612672610

Marcus Stoetzer, His Department Medizinische Hochschule Hannover, Abteilung für Mund-, Kiefer- und Gesichtschirurgie; Carl-Neuberg-Str. 1; 30626 Hannover; Germany; Tel: 00495115324748

II. MATERIAL AND METHODS

Materials

The experimental setup was designed to simulate different variables occurring during clinical application affecting the heat production. The piezosurgery system used in this study is the Piezosurgery 3 (Mectron,Carasco,Italy).

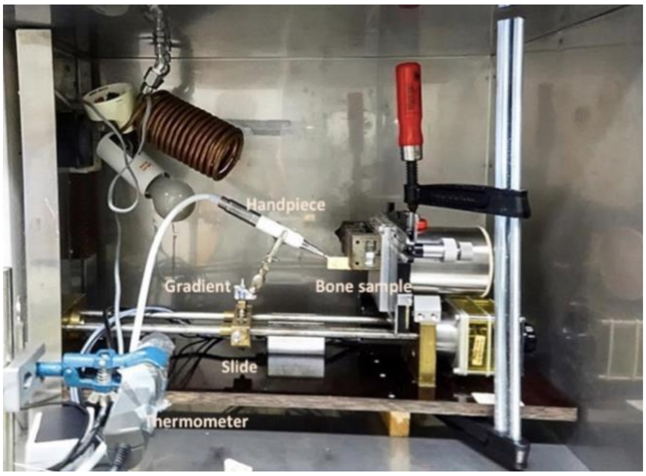

Fig 1 showes the experimental set up with clamped hand piece on the motor driven slide and a combination of 30° angulation as gradient and 0° rotation running on the surface of the fixated bone sample. The thermometer was put to side from its position for this purpose.

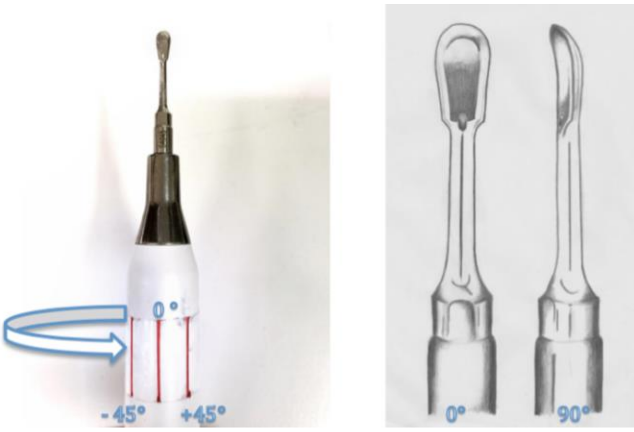

Fig 2 showes the tested corresponding tip for the preparation (PR 1, Mectron, Carasco, Italy). On the left: Handpice with working tip and zero mark, turning direction to the right. On the right: Outline of working tip, on the left in the optimal position (no rotation), on the right with 90° rotation. Saline solution (0.9%) was used for the cooling irrigation. The hand piece of the piezosurgery device was clamped on a motor driven slide. The speed of the slide can be varies in a reproducible matter. This device was constructed toenabled a height-adjustable fixation of the test samples. A special gripper connected to a self-designed software allowed the adjustment of different pressures between the hand piece and the samples. The measurement of the temperature was taken with an infrared thermometer (Tasco Infrared THI500,Tasco Japan,Osaka,Japan) using the software labVIEW Development System (National Instruments, Austin, USA).

For the investigations cattle ridges were used at room temperate (Metzgerei Willimann AG, Dagmersellen, Schwitzerland). Preliminary tests on pig ridges showed a forwar-speed of six centimeters per minute as a realistic speed simulating clinical conditions. For the investiagions the Piezosurgery 3 hand piece was clamped in different angulations and rotations combined with five different pressures. Therefore, the working tip was rotated in two different horizontal positions (15° and 30° rotation). Additionally, the handpiece was rotated in the longitudinal axis (0° and 90°) for each horizontal position. Each of the rotation combinations were carried out with five different pressures. A special gripper was used to examine the pressure on the bone samples. Prior to each test the cattle ridges cortical surface was carefully smoothed with a plaster grinder to reduce the influence of wrinkles and to enable a continuous, unhindered movement of the instrument on the bony surface. Totally 20 different combinations were tested, each test was repeated three times. The cooling irrigation (room temperature) was set up at a volume of 8ml per minute and the piezoelectric modulation was chosen as recommended by the manufacturer on "cortical". The heat measurements were continously taken at the range of one centimeter workflow every 0.5 sec with an error margin of 0,1°C over the period of 30 seconds per run. Preliminary tests had shown that the maximum heat acceleration was measured after 15-18 seconds working time.

Statistics

The collected data were analysed by the maximum temperature of every single passage. Statistical evaluation was performed with SPSS for Windows, Release 17.1 (SPSS Inc., Chicago, Ill, USA). Mann-Whitney U-test was used to determine significant differences ($p>0.05$) between the groups, as data were not normally distributed (Kolmogorov-Smirnov test, $p<0.05$). One-way ANOVA was used to evaluate the influence of the different experimental conditions (gradient, rotation, pressure) on the measured maximal temperatures

III. RESULTS

The results of the temperature development are summarized in both tabls.

Pressure	2.7 Nm	3.2 Nm	3.9 Nm	4.8 Nm	5.8 Nm
AngleRotation 15°0°	27.4 °C	27.1 °C	29.4 °C	27.6 °C	30.6 °C
	27.8 °C	27.5 °C	28.7 °C	27.8 °C	32.8 °C
	27.6 °C	27.9 °C	28.9 °C	28.6 °C	32.2 °C
30°0°	27.1 °C	27.4 °C	28.0 °C	28.3 °C	27.6 °C
	27.0 °C	27.2 °C	27.6 °C	28.4 °C	28.3 °C
	27.4 °C	27.4 °C	27.6 °C	28.1 °C	28.0 °C
15°90°	27.7 °C	27.7 °C	27.6 °C	28.0 °C	28.3 °C
	27.6 °C	26.6 °C	27.5 °C	27.0 °C	28.2 °C
	27.3 °C	26.6 °C	27.6 °C	27.0 °C	28.6 °C
30°90°	27.2 °C	27.7 °C	27.0 °C	28.0 °C	26.3 °C
	27.2 °C	27.0 °C	27.1 °C	27.8 °C	26.6 °C
	27.0 °C	27.2 °C	26.7 °C	26.5 °C	25.8 °C

Table 1 Overview of twenty different combinations related to the position of the handpice in vertical and horizontal dimension and the applied pressure.

Pressure (Nm) Angulation	2.7	3.2	3.9	4.8	5.8
15°/0°	27.60 (0.20)	27.50 (0.40)	29.00 (0.40)	28.00 (0.53)	31.90 (1.14)
30°/0°	27.17 (0.21)	27.33 (0.12)	27.73 (0.23)	28.27 (0.15)	27.97 (0.35)
15°/90°	27.53 (0.21)	26.93 (0.58)	27.57 (0.58)	27.87 (0.12)	28.37 (0.21)
30°/90°	26.87 (0.58)	27.30 (0.36)	26.93 (0.21)	27.43 (0.81)	26.23 (0.40)

Table 2 Results of the mean maximum temperature measurements for the different angulations an pressure combinations. Standard deviations in parenthesis.

The highest measured temperature was 32.8°C. It occurred from the combination of 0° rotations, 15° gradient and 5.8 Nm pressure. The lowest value of maximum heat 28.0 °C was measured at 30 gradients and 90° rotations.
The rotations of the angulation showed no statistically significant differences.

IV. DISCUSSION

The present study could show that under in vitro conditions the use of a new piezo derived raspatorium for periosteal preparation generated temperatures far below the critical temperature for bone necrosis. Statistical analysis resulted in significant difference in the heat development relating to angulation and pressure. To better simulate clinical conditions different angulation were tested since depending on the individual circumstances of the operative field, several positions of the periosteal elevator to the bone surface have to be applied in surgery. Transferred to physical dimensions these factors are the vertical and horizontal angulation of the instrument as well as the working pressure.
For a systematic investigation an in-vitro setup was chosen, where different angulations and rotations as well as different working pressures could be tested. The experimental setup met these requirements by the fixation of the handpice in two different vertical angulations (the gradient) and two different horizontal angulations (the rotation) on a moving slide with constant forward speed. Although the used bone is not of human origin, cattle ridge with its thick cortical layer has been shown to be similar to the mandibular [11] and to provide good comparison to human jawbone. For the experimental setup irrigation with saline solution at room temperature was chosen. This meets the criteria of clinical routine. Investigations using cooled irrigation would most likely result in less temperature at the working tip. Room tempered irrigation even confirmed to be sufficient for cooling the bone temperature below 47° C [19]. The temperature was measured with an infrared thermometer. The touchless method is well established in medical use [20, 21], even if the impact of the aerosol generated by the irrigation on the measurement is questionable and cannot be excluded in this experimental setup. Nonetheless, since conditions were equal for any groups the bias are systematic. A further limitation to the in-vivo situation is cause by physiological effects such as for example blood flow at the surgical site. Further in-vivo studies are necessary to specify this effects. The results showed a significant influence of the working longitudinal rotation angle on the heat development. This might be explained by the micromovements of the working tip. In angulated working tips the micro-vibration and thus the temperature acceleration is highest in the middle of the working tip as this part shows the highest movement and bending. As the working part of the working tip is closer to the middle due to the shape of the working tip, this results in higher temperatures. There is a controversy caused by previous observations confirming the rise of temperature depending on the applied pressure not only for conventional drilling [22] but also for ultrasonic devices [5, 14, 15]. Another study by Rahad could not show any influence of different loads nor irrigation volumes resulting in heat development [11]. The present results indicate an increase of the mean temperature in correlationm to higher pressure, implying an influence of the work load. Direct comparison to the results of other studies is difficult because devices designed to alter the bone or for implant site preparation were analyzed [5, 14, 15, 22]. The reossification as a main factor for success of most dental surgery treatments depends on the hard and soft tissue preservation [6, 14, 17, 18, 23]. Different studies constitute various heat levels, leading to hard tissue damages. Eriksson and Albrektsson established the temperature of 47°C over five minutes as the threshold for irreversible bone damage [13]. Latest in-vivo studies in low-density and dense bone states applying 60°C over a minute before implant insertion results in significant bone loss [24, 25]. Another in-vivo study by Yoshida reports that even when 48°C is applied for 15 minutes on the bone, bone formation eventually occurs, as the the periosteum and surrounding soft tissue strongly influences the bone remodeling [26]. Stoetzer confirms in an animal in-vivo study that histological examination of the subperiosteal preparation, using the piezodriven subperiosteal preparation tool, showed an impact of periosteal progenitor cells on bone remodeling [6]. Periosteum has been given an essential importance, because numerous studies have identified the existence of stem cells within the periosteum and that their activation plays a fundamental role to bone regeneration [18]. An in-vivo analysis of the effects of overheating the periosteum at a temperature of 42.5°C, resulted in positive effects like a steady increase in functional capillary density in the periosteum caused by induction of angiogenesis [27]. The study also analyzed the expression of the heat shock protein in the tissue. The expression of the heat shock protein (HSP) 70 was proportional to the intensity of the stress signal stimulus and could become a potential tool as a prognostic surgical marker [28]. Even though there is a need to evaluate the impact of HSP 70 in soft and hard tissue, the positive outcome resulted from animal testings in a 25 minutes period [27] whereas the expression as a stress marker was examined in human patients to compare two different surgical methods [28]. Further studies are needed to evaluate the impacts of heat on the periosteum and bone remodelling. The heat production only varies in very different positions of the angulation in correlation to the applied pressure, resulting in a recommendation for clinical use, especially when the cooling irrigation is set higher than minimal.

ACKNOWLEDGMENT

Compliance with Ethical Standards

Conflict of interest:
No conflict of interest for all authors.

Ethical approval:
This article does not contain any studies with human participants or animals performed by any of the authors./All applicable international, national, and/or institutional guidelines for the care and use of animals were followed./All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent:
For this type of study, formal consent is not required.

FIGURES AND TABLES

Fig1:
This photography showes the experimental set up with clamped hand piece on the motor driven slide and a combination of 30° angulation as gradient and 0° rotation running on the surface of the fixated bone sample. The thermometer was put to side from its position for this purpose.

Fig2: Handpice
On the left: Handpice with working tip and zero mark, turning direction to the right.
On the right: Outline of working tip, on the left in the optimal position (no rotation), on
the right with 90° rotation.

Table1:
Overview of twenty different combinations related to the position of the handpice in vertical and horizontal dimension and the applied pressure.

Table2:
Results of the mean maximum temperature measurements for the different angulations an pressure combinations. Standard deviations in parenthesis.

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