Comparison of piezosurgery apparatus: temperature rise and incision depth – preliminary studies

Maciej Michalak[1], Paweł Jarosz[2], Leszek Szalewski[3], Pola Bakalczuk[4], Andrzej Bożyk[1]

[1] Maestria Digital Dental and Face Clinic, Warszawa, Poland

[2] Engineering Studies Centre, The Institute of Technical Sciences and Aviation, The State School of Higher Education in Chełm, Poland

[3] Department of Integrated Paediatric Dentistry, Medical University of Lublin, Poland

[4] Diagnostic Techniques Unit, Medical University of Lublin, Poland

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Corresponding address:
Maciej Michalak,
michalak@ptss.pl
Maestria Digital Dental and Face Clinic
ul. Rodziny Hiszpańskich 8
02-685 Warszawa

Abstract

Osteotomy procedures can be done with the usage of different cutting apparatuses, which affect bone in different ways, therefore they can lead to micro fractures as well as thermal changes. The heat which is being released during preparation and insertion of the implants may have significant consequences for the bone, hence the range of the necrotic zone around the preparation area is directly proportional to the amount of heat generated. The purpose of this ex vivo experimental study was to evaluate the effect of different piezoelectric apparatuses with the use of the similar tips which worked on the temperature change and the obtained cutting depth, during the standardized 5 second osteotomies in the bone blocks from retracting porcine ribs. In this in vitro study, a total of 35 ostetomies, each for 5 second were performed using five different piezosurgical devices: Mectron Piezosurgery, Acteon Piezotome Cube STAR, Acteon Piezotome Cube Led, Piezomed W&H and NSK VarioSurg3 (detailed characteristic in Table 1) by a calibrated examiner and based on the manufacturer's guidelines for bone osteotomies.

Key words:

Piezosurgery;
Cutting force;
Cutting temperature;
Tissue damage

Introduction

Piezosurgery has been used for several years in orthopedic surgery, as well as in dentistry, especially in oral surgery and implantology as a method of osteotomy [1,2]. Piezosurgical devices work by applying electrical voltage on to the crystals, which expand and contract causing a vibratory movement to be transferred to the cutting tips of the device, therefore achieving very precise cuts [3]. In dentistry, this particular technique has been especially recommended for sinus lift procedures, because of its beneficial effect of osteotomy without damaging the Schneiderian membrane, due to the low-frequency ultrasonic vibrations which allow the cutting of mineralized tissue without damaging the structure of soft tissues [4,5]. Hence, piezosurgery is also recommended for the precise procedures in a small range and areas of the mouth where the risk of injury of the soft tissues is high.

There are many researches found in the literature, which show the existence of a number of advantages of piezosurgery in the field of dental implantology, such as: higher ISQ values, and thus greater implant stability than in the case of traditional drills [6], less bleeding [7], reduced postoperative swelling [8], faster bone remodeling and better bone healing than in the case of bone excised with a standard blade [9]. Not only does bone regenerates faster after piezosurgery, furthermore, it improves its density and lowers the level of Hsp70 protein, which is a "cell stress marker", which indicates a lower level of stress in the surrounding alveolar tissue than conventional surgery [10].

Osteotomy procedures can be performed with the usage of the various cutting devices, which have different effects on the bone, and therefore may lead to micro fractures and thermal changes [11]. The heat released during the preparation and insertion of implants can have significant consequences for the bone, and it was shown that necrotic zone around the preparation site is proportional to the amount of heat generated [12].

Recently, many authors have analyzed the thermal changes that occur during bone tissue surgery performed by piezosurgery. Stelzle i in. [13] used piezosurgery in an ex vivo study on porcine bone to prepare bearings for implants with a depth of 6 mm and a diameter of 3 mm. In their research, scientists showed that excessive force exerted on the tip increases the temperature rise in the developed tissue and recommends avoiding excessive vertical pressure (> 500 g) when making cuts in order to prevent temperature rises above 47°C. On the other hand, Schutz i in. [14] conducted an in vitro study in which they performed osteotomies on the jaws of pigs with a depth of 3 mm with the usage of different piezosurgical tips on a single piezosurgical device. They conclude that the type of tip which was used during the procedure can have significant impact on a thermal change during bone osteotomy. In the literature there is lacking amount of information which cover the impact of the choice of a piezosurgical device on temperature changes in the developed tissues when using similar cutting tips.

The main purpose of this ex vivo experimental study was to evaluate the effect of the different piezoelectric devices using similar working tips on the temperature change as well as the obtained cutting depth when performing standardized 5 second osteotomies in bone blocks obtained after dissection of porcine ribs.

Material and methods

In this in vitro study, a total of 35 ostetomies, each for 5 second were performed using five different piezosurgical devices: Mectron Piezosurgery, Acteon Piezotome Cube STAR, Acteon Piezotome Cube Led, Piezomed W&H oraz NSK VarioSurg3 (detailed characteristic in Table 1) by a calibrated examiner and based on the manufacturer's guidelines for bone osteotomies. In each of the devices a similar cutter was used. Incisions were made in porcine bone with D1-D2 density measured on the basis of CBCT scans (made with the Acteon X-Mind Trium 3D apparatus) using the AIS3DApp program. The incisions were made with a constant force perpendicular to the bone surface. Temperature changes were measured with a FLIR X6580sc thermal imaging camera equipped with a cooled InSb detector, which allows to obtain sharp, high-resolution thermograms with a thermal sensitivity <25 mK. Measurements were taken from the start of drilling, every 1 second and 5 seconds after the end of the device work. After the completion of the tests, the samples were re-examined to the CBCT (Acteon X-Mind Trium 3D) test and, based on the scans which were obtained, the cutting depths for each device were calculated. Figure 1 shows the device in operation, and Figure 2 shows a sample after making a series of cuts with each of the tested devices.

Statistical analysis

The mean maximum temperatures at the assigned measurement sites and incision depth were analyzed using Pearson's correlation coefficient test. The analyses were conducted using the Statistica software version 13 (Statsoft, Poland) at the significance level of 0.05.

Results

The obtained results of bone temperature changes during the cuts are summarized in Table 2. In Figure 3 unfortunately, the limited number of tests which were performed did not allow for statistically significant differences in relation to the model of the device used in the research. The lowest temperature rise was recorded for the Piezotome Cube LED Acteon (40.590C) and the highest average temperature was recorded for the Piezotome Cube Star Acteon (52.600C). Table 3 presents the results of the cut depth measurements obtained during the 5-second work of the devices. Moreover, statistical analysis did not show any statistically significant differences between the devices. The highest mean depth results were obtained for the Piezotome Cube LED Acteon (4.8 mm) and the lowest values for the Variosurg3 NSK (0.7 mm).

Fig. 1.
Tested devices

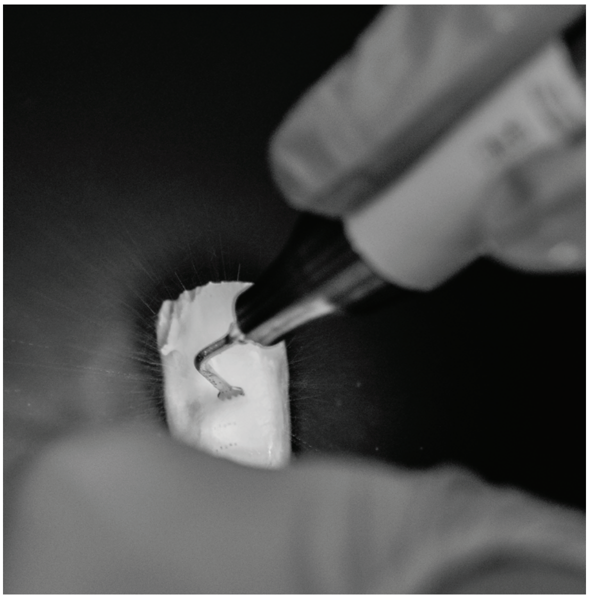

Fig. 2.
Working tip

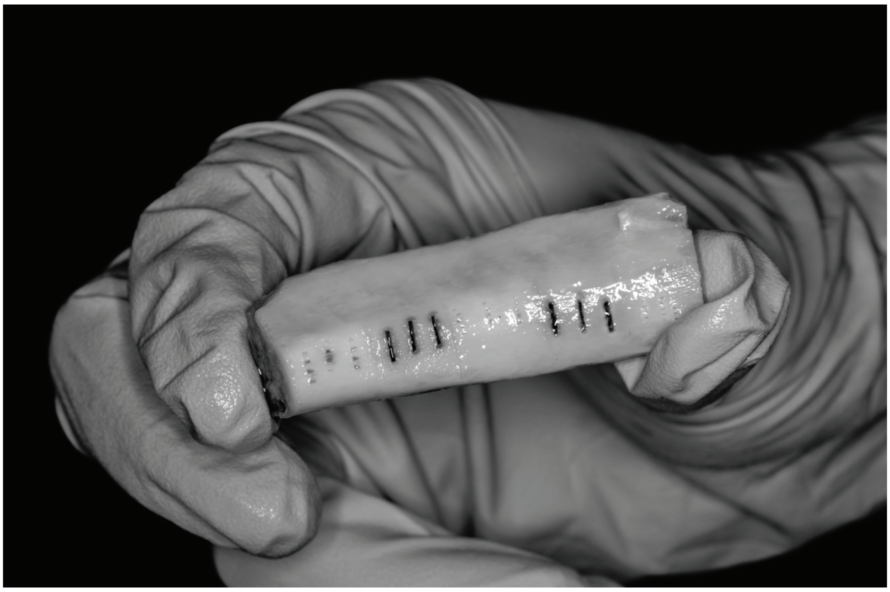

Fig. 3.
Bone with testing cuts

Table 1.
Characteristics of the devices used in the study

	Device	Manufacturer	Mode	Cooling	Tip
1	**Piezosurgery**	Mectron	cortical	max	OT6
2	**Piezotome Cube STAR**	Acteon	D2	max	BS1S
3	**VariosSurg3**	NSK	surgical	max	HSG1
4	**Piezotome Cube LED**	Acteon	D2	max	BS1S
5	**Piezomed**	W&H	100%	max	B1

Table 2.
Temperature changes during the test and 5 seconds after

	Initial tempera-ture	Maximum tempe-rature durning the cut	Increase in tem-perature durning the work of device	1 second after finished bone cut	2 second safter finished bone cut	3 seconds after finished bone cut	4 seconds after finished bone cut	5 seconds after finished bone cut
PIEZOSURGERY MECTRON	25.19	50.89	25.70	38.23	38.89	38.39	37.57	36.76
PIEZOMED W&H	26.05	42.06	16.01	35.63	36.60	36.69	36.68	36.39
VARIOSURG3 NSK	26.17	49.86	23.69	33.73	33.54	33.06	32.53	32.08
PIEZOTOME CUBE LED ACTEON	25.30	40.59	15.29	35.59	35.51	36.29	35.46	35.41
PIEZOTOME CUBE STAR ACTEON	25.15	52.60	27.45	38.18	38.60	39.51	39.61	39.89

Table 3.
Average cut depths carried out for 5 seconds

	n	Minimum depth [mm]	Maximum depth [mm]	Mean depth [mm]	SD
PIEZOSURGERY MECTRON	3	0.6	1.2	1.2	0.91
PIEZOMED W&H	3	0.2	0.5	0.8	1.09
VARIOSURG3 NSK	3	0.2	0.4	0.7	1.11
PIEZOTOME CUBE LED ACTEON	3	5	5.2	4.8	0.86
PIEZOTOME CUBE STAR ACTEON	3	3	6.2	4.2	1.6

Discussion

Bone tissue shows low thermal conductivity. Heat which is being generated during bone preparation does not disappear quickly, but rather remains around the site of the done osteotomy [15]. It has been suggested that if the temperature rises above 47 degrees Celsius and these values remain for at least one minute, it may lead to bone necrosis in this area [16,17]. In our reaserch, three out of five devices showed an increase in temperature above 47°C, however these values were only temporary and decreased to a temperature safe for the bones. 5 seconds after the end of the device work, the maximum temperature was below 40°C. Due to the existing dependence of temperature and time, it is advisable that the procedures with the use of piezosurgical devices can be performed quickly without exposing the tissues to excessive overheating. Moreover, the temperature increase, may also be influenced by the repeated use of the same drills/tips, reducing their efficiency [18]. However, even new drills/tips, depending on their shape, sharpness, speed used or applied axial load, may have an impact on temperature changes in the developed tissue [19-23]. Should not be forgotten about the tissue itself, which undergoes preparation, the density of the developed bone has a significant impact on the duration of the procedure as well as the temperature changes. Yacker and Klein [24] found in their studies that bone density has a greater influence on the temperature increase than the cutting depth.

All in vitro studies have their limitations. The baseline test stand temperature in our study was lower than the temperature within the human body. The effects of thermal absorption within the microcirculation of natural tissue of bone, potentially leading to lower values during cutting, were not taken into account in the tests. Human bone may also exhibit features other than animal bone. On the other hand, in our own research, we obtained the perfect cooling, which during clinical work may be limited by soft tissues and a surgical tool blocking the access of water to the cut tissues.

Conclusion

Based on the preliminary studies, it can be concluded with high probability that piezosurgery devices differ in the cutting efficiency with a comparable increase in bone temperature. It is advisable to continue research with more variables and repetitions in order to unequivocally confirm this hypothesis. It would also be desirable to design a device that applies a constant pressure of the piezosurgical tip to the sample to unify the research.

References

1. Pavlikova G., Foltan R., Horka M., Hanzelka T., Borunska H. Sedy J. Piezosurgery in oral and maxillofacial surgery. International Journal of Oral and Maxillofacial Surgery 2011; 40: 451–457.
2. Pereira C., Gealh W., Meorin-Nogueira L., Garcia--Junior I. Okamoto R. Piezosurgery applied to implant dentistry: clinical and biological aspects. Journal of Oral Implantology 2014; 40: 401–408.
3. Yaman Z. & Suer B. Piezoelectric surgery in oral and maxillofacial surgery. Annals of Oral and Maxillofacial Surgery 2013; 1: 1–9
4. Wallace, C., Mazor, Z., Froum, S., Cho, S. & Tarnow, D. Schneiderian membrane perfo- ration rate during sinus elevation using piezo- surgery: clinical results of 100 consecutive cases. International Journal of Periodontics and Restorative Dentistry 2007. 27: 413–419.
5. Seshan, H., Konuganti, K. & Zope, S. (2009) Piezosurgery in periodontology and oral implantology. Journal of the Indian Society of Periodontology 13: 155–156.
6. Stacchi, C., Vercellotti, T., Terelli, L., Furlan, F. & Di Lenarda, R. Changes in implant stabil- ity using different site preparation techniques: twist drills versus piezosurgery. A single-blinded, randomized, controlled clinical trial. Clinical Implant Dentistry & Related Research 2013,15: 188–197.
7. Jose, A., Nagori, S., Virkhare, A., Bhatt, K., Bhutia, O. & Roychoudhury, A. Piezoelectric osteoarthrectomy for management of ankylosis of the temporomandibular joint. British Journal of Oral and Maxillofacial Surgery 2014; 52: 624–628.
8. Sortino, F., Pedulla, E. & Masoli, V. The piezoelectric and rotatory osteotomy technique in impacted third molar surgery: comparison of post- operative recovery. Journal of Oral and Maxillo-facial Surgery 2008; 66: 2444–2448.
9. Ma, L., Stu€binger, S., Liu, X., Schneider, U. & Lang, N. Healing of osteotomy sites applying either piezosurgery or two conventional saw blades: a pilot study in rabbits. International Journal of Orthopaedics 2013; 37: 1597–1603.
10. Gülnahar, Hüseyin Köşger H. Tutar, Y. Comparison, A of piezosurgery & conventional surgery by heat shock protein 70 expression. The International Journal of Oral and Maxillofacial Surgery 2013; 42: 508–510
11. Shank, S., Beck, F., D'Atri, A. & Huja, S. Bone damage associated with orthodontic place- ment of miniscrew implants in an animal model. American Journal of Orthodontics and Dentofacial Orthopedics 2012; 141: 412–418.
12. Weinlaender M. Bone growth around dental implants. Dent Clin North Am 1991;35:585–601.
13. Stelzle F, Neukam F, Nkenke E. Load-dependent heat development, thermal effects, duration, and soft tissue preservation in piezosurgical implant site preparation: an experimental ex vivo study. The International Journal of Oral & Maxillofacial Implants 2012; 27: 513–522.
14. Schütz S, Egger J, Kühl S, Filippi A, Lambrecht JT. Intraosseous temperature changes during the use of piezosurgical inserts in vitro. The International Journal of Oral and Maxillofacial Surgery 2012; 41: 1338–1343.
15. Mustafa, B. & James, D. Temperature rise during drilling through bone. The International Journal of Oral & Maxillofacial Implants 1997; 12: 342–353.
16. Lundskog, J. Heat & bone tissue. An experimental investigation of the thermal properties of bone & threshold levels for thermal injury. Scandinavian Journal of Plastic and Reconstructive Surgery 1972; 9: 1–80.
17. Eriksson A, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: a vital--microscopic study in the rabbit. Journal of Prosthetic Dentistry 1983; 50: 101–107.
18. Scarano A, Carinci F, Quaranta A, et al. Effects of bur wear during implant site preparation: an in vitro study. Int J Immunopathol Pharmacol 2007;20:23–6.
19. Misir AF, Sumer M, Yenisey M, et al. Effect of surgical drill guide on heat generated from implant drilling. J Oral Maxillofac Surg 2009;67:2663–8.
20. Scarano A, Piattelli A, Assenza B, et al. Infrared thermographic evaluation of temperature modifications induced during implant site preparation with cylindrical versus conical drills. Clin Implant Dent Relat Res 2011;13:319–23.
21. Stelzle F, Frenkel C, Riemann M, et al. The effect of load on heat pro- duction, thermal effects and expenditure of time during implant site preparation – an experimental ex vivo comparison between piezosurgery and conventional drilling. Clin Oral Implants Res 2014;25:e140–8.

22. Benington IC, Biagioni PA, Briggs J, et al.Thermal changes observed at implant sites during internal and external irrigation. Clin Oral Implants Res 2002;13:293–7.
23. Marković A, Mišić T, Miličić B, et al. Heat generation during implant placement in low-density bone: effect of surgical technique, insertion torque and implant macro design. Clin Oral Implants Res 2013;24:798–805.
24. Yacker M, Klein M. The effect of irrigation on osteotomy depth and bur diameter. Int J Oral Maxillofac Implants 1996;11:634–638.