Intraosseous heat generation during guided osteotomy for dental implantological purposes

Summary of the PhD thesis

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Szeged, 2018

Introduction

Prosthodontically driven implant surgery has been subject of interest to dental professionals for the past decade. The correct positioning of implants has a number of obvious advantages, such as favourable functional and aesthetic outcomes, better occlusion and less chance of implant overload, to mention just a few. A well-positioned implant can also make it easier for the patient to maintain good oral hygiene, once the superstructure has been inserted.

Thermal osteonecrosis, thermal damage

As the application of metal implants has become routine in musculoskeletal trauma surgery, orthopaedic surgery, spine surgery, cranio-maxillofacial surgery, dentistry and oral implantology, drilling of bone has also become one of the most common basic surgical steps. As for the healing of the osseous structure, this can be influenced by several factors including implant design, chemical composition, the material and shape of the implant, the physiological characteristics of the host bone bed, loading conditions, the topography of the implant surface, the healing potential of the host bone, the use of adjuvant treatments, pharmacological agents and also heat generation during osteotomy. The bone tissue is very vulnerable to thermal injury, and the temperature threshold for tissue survival during osteotomy is 47˚C when drilling is maintained for more than 1 minute. Therefore, it is critical for successful osseointegration to keep heat generation under control during osteotomy. Excess heating above this limit can lead to the primary failure to of osseointegration.

The guided approach to oral implantology

In the last few years a rapid development could be observed in the field of computer-assisted implant placement. Increased beneficial use of computers was made possible through the recent advances in computer technology, which allowed the planning and the execution of various steps involved in dental reconstructions during the placement of dental implants. The above mentioned novel possibilities include computer assistance for the planning of surgical interventions, for the implementation of the surgical steps, for capturing intraoral situation and also for designing temporary and final prosthetic solutions or even for the manufacturing of prosthetic components.

Combining the cone-beam computed tomography (CBCT) images with an implant planning software has made it possible to virtually plan the optimal implant positions, in regard of the future prosthetic needs and the vital anatomical structures. This information can be used to fabricate a drill guide, which ultimately results in the transfer of the planned implant position from the computer to the patient, with the guide directing both the osteotomy and the insertion of the implant.

Aims and Hypotheses

The present thesis sought to find answers to the following questions:

1. How does the effect of the combination of low-speed drilling and cooled irrigation fluid influence intraosseous temperature elevation during guided and freehand implant surgery?
   Our hypothesis was that with the combination of low-speed and cooled irrigation fluid we can control the temperature increment in such a way that with any of the drilling procedures it will be

avoidable to do thermal damage to the bony structure.

2. How does drill wear and consequent intraosseous temperature elevation during freehand and guided bone drilling change, with special attention to the effect of metal-on metal contact during guided drilling? We hypothesized that the metal-on-metal contact would damage the surface of the drilling bits, and therefore it would be associated with significantly higher temperatures during the drilling procedures.
3.

Materials and methods

Bone model

Bovine ribs were used for the experiments because of their favourable anatomical and thermophysical

The cortical bone thickness of the mandible falls in a range of approximately 1.0-2.0 mm for edentulous and 1.6-2.0

for dentate bone. The specimens selected were in the above-mentioned range.

Setup

Drillings were performed for every step of the drilling sequence (diameters of 2.0, 2.5, 3.0, and 3.5 mm) at a drilling speed of 800 rpm, comparing freehand versus guided surgery and the use of irrigation fluids at different temperatures (20°C, 15°C, and 10°C).

In our second investigation three different groups of sterilization were defined as follows: drill bits cleaned only by running water, no other chemical or physical contact (control protocol, CP); drill bits cleaned with a soft brush using a standard disinfectant solution (Gigasept Instru AF, Schülke and Mayr, Germany), which was followed by 5 minutes of ultrasonic cleaning (Ultrasonic Cleaner JP-010, Digital Pro+, China), then a 20-minute-long sterilization program at 134°C (Quick Program S) in an autoclave (Vacuklav 24 B+, MELAG,Germany)–soft protocol (SP); drill bits cleaned with a rough brush using the same disinfectant solution as in group SP, followed by a 50-minute-long sterilization program at 134°C

(Universal Program) in the same autoclave as under SP (rough protocol, RP) Drill bits of 2.0 mm diameter were used from the tray of the SMART Guide System (Smart Dental Kft., Szeged, Hungary). Osteotomies were performed at the speed levels of 800, 1200, 1500 and 2000 rpm. After every third osteotomy we performed a cleaning/sterilization cycle.

Studies suggest that the maximum temperature increment can be observed in the cortical layer of the bone. Therefore, we performed temperature measurements in the cortical layer of the bone. K-type thermocouples were used for temperature measurements with a connected measurement device (HoldPeak 885A, HoldPeak; Zhuhai,Guangdong, China).

A constant axial load of 2.0 kg was used. A bench drill with adjustable drilling speed was used for the experiments (Bosch PBD 40; Bosch, Stuttgart, Germany).

Constantly controlled external irrigation was provided by a widely known, accepted and used surgical unit (W&H Implantmed SI-923; W&H, Bürmoos, Salzburg,Austria).

Collection of data and statistical analysis

Baseline and peak temperatures were collected to one decimal point in a spreadsheet file Microsoft Excel 2013 (v15.0) (Microsoft Corporation, Redmond, WA, USA). Temperature elevations were calculated as peak temperature minus baseline temperature to one decimal point using the spreadsheet. The values were statistically analysed using Statistica for Windows 10.0 (Statsoft, Tulsa, OK, USA). Normality of distributions was tested with the Shapiro-Wilk test. As for the hypothesis testing, one-way ANOVA with post-hoc Tukey HSD and Kruskal-Wallis ANOVA were used, as appropriate according to the normality of the distribution.

In the second investigation the data were analysed in SPSS23.0 (Armonk, New York, United States: IBM). For the comprehensive analysis of the data, factorial ANOVA was used, with temperature increment as the dependent value, sterilization protocol, and drilling speed, and the total number of osteotomies performed as factors. Besides the descriptive statistics, groups defined by the sterilization protocol and the total number of osteotomies were compared with one-way ANOVA (with Tukey post hoc analysis). As multiple comparisons were performed, the level of significance was calculated individually for each and every analysis by the software

Results

In some instances, the use of irrigation fluid cooled to 10°C combined with low-speed drilling (800 rpm) resulted in negative temperature changes as compared to the baseline. This phenomenon was more pronounced for smaller drill diameters (2.0 and 2.5mm). No mean temperature change exceeded+1.0°C when using irrigation fluid cooled to 10°C, regardless of the drill diameter or the drilling method (freehand or guided). The temperature change was significantly lower using irrigation fluid cooled to 10°C compared with the result with the same diameter drilling with irrigation at room temperature, for every investigated drill diameter, regardless of the drilling method.

The most important findings for guided osteotomies are as follows: at 800 revolutions per minute, the first significant temperature increment as compared to the baseline was detected after 90 osteotomies under the control sterilization protocol ($p < 0.001$) and the rough sterilization protocol ($p < 0.001$). Interestingly, significance was reached earlier under the soft sterilization protocol after only 60 osteotomies ($p = 0.04$). Once statistical significance was reached, temperature continued to increase in significant steps ($p < 0.0001$) under all protocols up to 210 osteotomies.

At 1200 rpm the results for guided osteotomies were the following: the first significant temperature increment as compared to the baseline was detected after 30 osteotomies under CP ($p < 0.01$) and SP ($p < 0.01$). Unexpectedly, under RP, it took longer, 60osteotomies, to reach statistical significance ($p < 0.001$). Once statistical significance was reached, temperature continued to increase in significant steps ($p < 0.001$) under all protocols up to 120 osteotomies.

The observations at 1500 rpm were the following for the guided osteotomies: the first significant temperature increment as compared to the baseline was detected after 30 osteotomies under RP ($p < 0.001$). Under SP, it took 60 osteotomies to reach significance ($p < 0.001$). Regarding osteotomies with drills treated according to CP, significance was reached only at 90 osteotomies, which was the maximum at this speed ($p < 0.01$). Once statistical significance was reached, temperature continued to increase in significant steps ($p < 0.001$) up to 90 osteotomies.

The measured temperature increments at 2000 rpm for guided osteotomies were the following: the first significant temperature increment, as compared to the baseline was detected at 60 osteotomies under RP and SP ($P < 0.001$). Under CP, significance was reached at the maximum 90 osteotomies ($P < 0.001$). Under SP, it took 60 osteotomies to reach significance ($P < 0.001$). Once statistical significance had been reached, temperature continued to increase in significant steps ($P < 0.001$) up to 90 osteotomies.

Discussion

In the present thesis, we sought, first of all, to examine the effect of several factors that we believed would significantly contribute to heat generation during osteotomy: the presence of the metal sleeve in the surgical template and the combination of different drilling speed with different temperature irrigation fluids. The effect of metal to metal contact was compared with freehand osteotomy, and 3 further factors, sterilization, drilling speed, and drill wear, were also considered. To summarize the findings, at 800rpm, the intraosseous temperature never reached the necrotic threshold in any of the examined conditions during the total of 210 osteotomies. At higher drilling speeds, 90 osteotomies could be safely (i.e., without approaching 47°C) performed regardless of the applied sterilization protocol and whether the drilling was performed freehand or through a metal guide. The results also show that whether guide use led to a near-necrotic temperature increment depended largely on the applied sterilization protocol. In general, our hypothesis regarding the significant and cumulative effect of each studied factor during the experiments regarding the drill wear has been confirmed. It has been proven that the metal guide sleeve contributes significantly to heat generation during osteotomy, but this does not mean a safety risk if a soft sterilization protocol is used. As for temperature elevations in guided osteotomy our results suggest that the use of a low drilling speed of 800 rpm combined with the external irrigation fluid being cooled to 10°C can result in a mean cortical intraosseous temperature change being below 1.0°C, regardless of drill diameter or drilling method (freehand surgery or guided surgery). All in all, the literature almost unequivocally suggests that guided osteotomy (with a metal sleeve) does not pose an extra safety risk in terms of temperature elevation, which is in agreement with our results.

Conclusions

Based on the results of the investigations that provide the basis of the present work, a low drilling speed with cooled irrigation are recommended when performing osteotomy through a surgical guide. 800 rpm and 10°C proved to be optimal in our experiments. Furthermore, drills that are used for guided osteotomy should be taken care of with extra precaution regarding the cleaning and the sterilization protocols and their use (the drill bits) should be maximized at a level of 90 osteotomies.

Acknowledgements

I would like to thank Professor József Piffkó, MD, DMD, PhD for his belief in me and my ability to complete this thesis and the support and knowledge which guided me over the last period of my career.

I would like to express my appreciation towards Kristof Boa, MD. His friendship, precision, positive mentality and calm temper has helped me through the obstacles encountered during our scientific work.

It is a great pleasure to acknowledge the support of Dr. Gábor Braunitzer, PhD who deserves a special place among those mentioned here for the ideas we share and for always being a source of great advice whenever I face difficulties in research.

The presented research would not have been possible to perform without the SMART Guide team. I would like to express my gratitude to Endre Varga Jr., DMD, PhD, Károly Bagi, and everyone else at dicomLAB Ltd. for their supporting our studies with both material and professional contributions.

This thesis would not have been possible without the background provided by my family. I would like to express my gratitude towards my parents, Éva Herczeg MD and Ahmad Barrak MD for their constant support throughout my whole life. A special thanks goes to my two lovely sisters: Sausan Barrak DMD and Nora Barrak DMD, who guide me in the field of dental medicine.

Finally, I would like to thank to a very special person in my life, my beautiful wife, Lilla Majzinger DMD who always supports my ideas whether they are good or bad and without her help this thesis would have remained a dream.