FACTORS AFFECTING BONE TEMPERATURE INCREASE DURING IMPLANT SURGERY – REVIEW

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ABSTRACT

INTRODUCTION: During implant surgery certain amount of heat is produced. It is known that temperature increase above the critical threshold of 47°C for a minute could lead to thermal osteonecrosis, which could be the reason for an early implant failure.

AIM: The aim of this review was to reveal the multifactorial nature of bone temperature rise during dental implant surgery.

MATERIALS AND METHODS: PubMed and Google Scholar databases were searched to select articles related to the topic. The review includes articles published from 1972 to 2019, only in English language.

RESULTS: All reviewed original articles, describing studies, whose aim was to observe the heat generation during implant surgery, are experimental. A few reviews were included. As potential risk factors for thermal damage of the bone were considered the site preparation protocol, drill wear, drill design, drilling speed and cooling effectiveness.

CONCLUSION: Heat generation during implant site preparation could be increased by performing guided implant or piezoelectric surgery. The use of combined irrigation at higher speeds, sharper drills and laser-assisted osteotomy could help avoid the risk of thermal damage to the bone. The heat production during the implant site preparation is a subject to many studies, but there is still a lack of data about the temperature rise during implant insertion.

Keywords: *heat generation, implant site preparation, temperature*

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INTRODUCTION

During implant surgery a certain amount of heat is produced. It is known that temperature increase above the critical threshold of 47°C for a minute could lead to thermal osteonecrosis, which could be the reason for an early implant failure.

AIM

The aim of this review was to reveal the multifactorial nature of the bone temperature rise during dental implant surgery.

MATERIALS AND METHODS

PubMed and Google Scholar databases were searched to select articles related to the topic. The review includes articles published from 1972 to 2019, only in English language. The search was performed using a combination of different keywords such as: "implant", "heat generation", "temperature", "cooling", "irrigation", "drill wear", "infrared thermography", "thermocouples", "placement", "insertion", "site preparation", "osteotomy", "ultrasonic", "piezoelectric", "laser", "guided", "drilling speed", "load".

The critical temperature, leading to thermal osteonecrosis is 47°C for one minute (1).

According to the literature review data, heat generation during the implant site preparation is mostly measured using thermocouples and infrared thermography (2-11).

Comparing both methods Harder et al. (12) considered thermography as more reliable in terms of measuring the intraosseous heat production during implant bone bed preparation. Möhlhenrich et al. (2) also recommended the use of infrared thermography for heat generation assessment.

Different biomechanical factors influence the increase in temperature during the preparation of osteotomy. Bone temperature rise is a result of multiple factors, and it should be decreased in order to achieve better tissue healing (13).

Different Site Preparation Methods and Conventional Drilling

◈ Guided Implant Surgery

Frösch et al. (14) compared the heat generation during guided osteotomy preparation with that generated during a conventional approach. For both methods they performed a single and sequential drilling protocol. The osteotomy was done in polyurethane foam blocks and the heat development was assessed using an infrared camera. Their results demonstrated that guided osteotomy preparation as well as sequential drilling leads to heat generation. Authors suggest single drilling protocol during guided implant surgery in order to decrease the temperature rise (14). Other authors also conducted similar study (15). Investigating the subsequent bone temperature increase during freehand and guided bone drilling, especially the influence of metal-on-metal contact during guided osteotomy, Barrak et al. (15) concluded that the metal sleeve contributed significantly to the temperature rise. During guided implant surgery temperature could be controlled using appropriate drilling speed and irrigation solution cooled to certain temperature (16,17). Misir et al. (18) concluded that the guided implant surgery led to higher temperature increase than the conventional approach.

◈ Reduced Number of Drills

El-Kholey et al. (19) prepared 120 implant beds into bovine ribs. Half of the osteotomies in the same diameter group were done using only the pilot and the final drill and the other half were performed by the conventional drilling protocol. Heat generation was measured using thermocouple and a sensitive thermometer. The authors came to the following conclusion: both techniques lead to a development of similar temperature. Mihali et al. (20) suggested that drilling protocol including only the first and the last drill is safe for implant bed preparation. The authors also commented, that the mentioned protocol was significantly less time-consuming than the conventional approach. In an experimental study it was established that implant site preparation protocol using only one drill in type IV bone, performed under the following conditions: drilling speed of 50, 150 and 300 rpm, without cooling, led to a temperature rise that did not exceed 47 °C (21). In another study it was concluded that the single drilling approach could lead to a higher temperature rise than the conventional drilling protocol (10).

◈ Ultrasonic Implant Site Preparation

Ultrasonic implant bone bed preparation is a highly accurate method (22), which demonstrates certain advantages, such as less pain and swelling (23).

Rashad et al. (24) observed higher heat generation with the ultrasonic implant bed preparation, whose performance requires more time. According to the authors higher temperature rise during the ultrasonic approach could be decreased with a higher level of irrigation. Other authors also established significantly higher heat production during osteotomy using piezosurgery unit compared to the conventional drilling (25). Stelzle et al. (26) concluded that the implant bed preparation using piezoelectric surgery should be performed with a maximum load of 400 g to avoid thermal tissue changes. The authors also compared the duration of the implant bed preparation using piezoelectric surgery, spiral and trephine burs and concluded that the first one required more time. The results obtained in other study were as follows: the temperature that was generated during the use of both systems - rotary burs and piezoelectric tips was safe in regard to tissue healing (27).

- Laser-Assisted Preparation

Although dental lasers are frequently used for the purpose of periodontal treatment (28-30), they could also be used for implant site preparation (31-36). During the laser-assisted implant site preparation the bone heat generation was monitored because of the risk of thermal trauma on soft and hard tissue (31). According to Zeitouni et al. (33) the laser bone bed preparation resulted in a reduced thermal damage compared to the conventional drilling. The right selection of the wavelength and parameters of the laser plays a key role in avoiding the possibility of thermal bone trauma (34). Although osteotomy preparation using a bur is less time-consuming, the use of Er:YAG laser seems to cause less thermal damage of the bone. Comparing the three instruments for osteotomy - bur, Er:YAG laser and Er,Cr:YSGG, the latter was the only one, which caused carbonization (37).

Drill Wear

The different roughness of the drill surface could lead to different heat generation during drilling (38). Lower temperature rise was observed with sharper drills (39). Other authors also support the point that the use of worn drills leads to much higher heat generation than that of the new ones (40). Ercoli et al. (41) concluded that the bone bed could be prepared safely with drills that were used several times. Fugito Junior et. al (27) concluded that the wear of rotary burs, as well as the wear of piezoelectric tips, did not lead to a significant temperature rise after the preparation of 30 implant beds. Er et al. (42) conducted a study, whose aim was to extend the lifetime of the implant drill and its performance by using heat- and wear-resistant protective coatings to decrease the alveolar bone heat generation during the osteotomy procedure. Other authors also support the opinion that the number of uses of the drills affects the generated temperature during osteotomy (43, 44).

Drill Design

According to Scarano et al. (45), who used infrared thermography to detect the differences in heat production during implant site preparation with conical and with straight drills, the drill geometry is an important factor with respect to heat generation. Other authors came to the similar conclusion (44).

Other authors also did not observe a relationship between the temperature rise and drill design in the single-drilling approach using speed in the range of 50 to 300 rpm (21).

It was established that the drill diameter affected the heat generation (10). It was observed that the twist drills even of a smaller diameter (2 mm) caused higher heat generation than the conical drills of a larger diameter (3.5 mm) (46). Comparing the temperature rise during drilling using drills made of ceramic and stainless steel, Sumer et al. (47) observed statistically significantly higher temperature increase only at the osteotomy depth of 3 mm using ceramic drill. Measuring the heat generation at depth of 6 and 9 mm they did not establish any significant difference between stainless steel and ceramic drills.

Drilling Speed

Drilling speed during osteotomy is one of the factors affecting the bone temperature increase (16,17,39, 48-50). Temperature rise was positively influenced by the drilling speed, when it increased from 400 rpm to 10 000 rpm (48). Other authors also commented on the direct relationship between higher rotational speed and heat generation (39). For guided implant surgery drilling speed of 800 rpm was proposed (16) and drilling speed of 1500 rpm and 2000 rpm led to heat generation that exceeded the critical threshold (17).

Comparing the temperature rise during drilling with a speed of 1225 rpm, 1667 rpm, and 2500 rpm Sharawy et al. (49) found the higher drilling speed used as a safest from a bone overheating standpoint. Using a speed of 2000 rpm, 30 000 rpm and 400 000 rpm Iyer et al. (50) established an inverse relationship between the temperature increase and the drill speed.

In regard to the bone temperature rise during drilling the combined effect of the drilling speed and the pressure applied was commented (48,51).

Applied pressure

Commonly used pressure is about 2 kg (2,18,47,52,53). Lajolo et al. (25) did not establish a statistically significant effect of pressure load of 1 kg and 1.5 kg on the heat production. Rashad et al. (24) did not observe a difference in the heat generation with higher loading. At speed of 400 rpm and 800 rpm the increase of the drilling load from 0.8 kg to 2 kg had little influence on temperature rise (48).

There is a temperature rise at the implant surface during nonsurgical procedures (54,55), as the generated heat could also be transferred to the surrounding bone (56,57).

Cooling

Implant site preparation using inadequate cooling methods could lead to thermal trauma of the bone, followed by cortical bone resorption and failure of the implant treatment (58).

There is a difference between the heat produced during implant bed preparation using internal and external cooling (59).

In an ex vivo study it was established that the combination of internal and external irrigation leads to a significantly lower heat generation compared to external irrigation only (6). Another study compared the temperature rise caused by internal, double and external irrigation of conical drills and concluded that the latter led to significantly higher temperature increase than the other two mentioned (46). Trisi et al. (58) also considered internal and combination of internal and external irrigation more reliable than external irrigation only. The authors also reported extreme cortical bone resorption around implants inserted into sites prepared without irrigation. Another study also established that double irrigation and internal irrigation caused less heat generation than external cooling (52). There is an implant site preparation protocol, where only the pilot drill is with external irrigation and the following drills are with combined irrigation – internal and external (60).

Sindel et al. (61) investigated the impact of the irrigation volume on the bone temperature rise during implant surgery. The measurements were done using thermocouples inserted into a sheep mandible bone. The heat generation was assessed in three irrigation groups: without irrigation and with a physiological saline irrigation of 12 mL/min and 30 mL/min. While the heat generation in the no-irrigation group was significantly higher than that of the other two groups, included in the study, no statistically significant difference between both irrigation groups: 12 mL/min and 30 mL/min, was observed . According to the authors the amount of heat produced during drilling did not correspond directly to the volume of the cooling solution. Certain irrigation solution volume is enough with regard to safe implant site preparation, while additional cooling could lead to impaired visibility in the area. Other authors used infrared thermography to assess the heat production during preparation using cooling solutions of different temperature (62). The effect of the irrigation solution volume on the heat production at the cortical bone area depends also on the implant site preparation technique. It was established that higher irrigation during the ultrasonic approach led to decreased temperature rise in the cortical bone, while the same relationship was not observed with the conventional drilling technique. This effect of the cooling during ultrasonic implant bed preparation was associated with a significant difference in the temperature between the cortical and the cancellous bone (24).

For guided implant bed preparation the use of 10 °C cooling solution was considered safe in regard to the temperature rise (16,17).

Comparing the heat production during experimental preparation using drilling speed of 50 rpm without irrigation and drilling speed of 1500 rpm with irrigation, Oh et al. (63) did not observe any statistically significant difference between the temperature rise in both groups. Other authors also established that although the absence of irrigation at drilling speed of 50, 150 and 300 rpm caused temperature increase, it did not rise above 47 °C (21). Low-speed drilling at 50 rpm without irrigation seemed to be safe in terms of bone overheating (64). According to another study the critical threshold was exceeded with a speed of 1500 rpm without irrigation (62).

Flanagan (65) and Marković et al. (66) investigated the heat generated during implant insertion using thermocouples. According to Summer et al. (67)

manual placement of an implant and insertion at speeds of 30 rpm and 50 rpm leads to lower heat generation compared to insertion at 100 rpm. Infrared thermal camera was also used to observe the temperature increase during implant insertion (68). It was establish that the temperature rise during implant insertion could be reduced by placing tapered, shorter and smaller diameter implants (68).

RESULTS

All reviewed original articles describing studies, whose aim was to observe heat generation during implant surgery, are experimental. Among all of them only four were related to the temperature rise during implant insertion as the subject of the majority of the articles was heat generation during implant site preparation. A few reviews were included. The site preparation protocol, drill wear, drill design, drilling speed and the cooling effectiveness were considered potential risk factors for thermal damage of the bone.

DISCUSSION

Although it was established that the temperature rise during guided implant bed preparation could be controlled by the right choice of available options (14,16,17), it seems that the conventional drilling is the safer approach (14,15,18).

The reduced drill number protocol, including two drills, seems to be safe enough for implant site preparation (19, 20), leading to heat generation comparable to that caused by the use of conventional drilling (19).

The use of the piezosurgery unit leads to higher temperature rise during osteotomy (24, 25) and is more time-consuming than the conventional protocol (23,24,26). To minimize the risk of thermal trauma of the bone, the method should be performed under the following conditions: higher level (24) of irrigation and maximum load of 400 g (26).

With the right selection of wavelength and other parameters (34), laser-assisted osteotomy could be used as an alternative to conventional drilling from a safety standpoint, resulting in even less thermal damage (33, 37). However, it should be taken into account that laser osteotomy consumes more time than bone drilling (37).

Most of the authors support the opinion, that the wear of the drills affects the heat generation during implant site preparation (38, 40, 43, 44). Some authors considered the acceptable number of uses of the drills (27, 44, 69).

In regard to the effect of the drill design on heat generation during osteotomy, the results reported by the different authors are controversial. Both theories were supported, with a little prevalence of the design significance theory (45,44,46) over the opposite one (21).

Implant bone bed preparation without irrigation is acceptable during low-speed drilling at 50 rpm (21,63,64). At higher speed the use of cooling solution is required (62), as the internal and the combination of the external and internal irrigation are superior compared to external irrigation only (6,46,52,58). Although according to some authors the increase of the drilling speed affects the temperature rise directly (39,48), it should be taken into account that lower speed drilling consumes more time (21) and the combination of the increased temperature and its duration could lead to thermal bone trauma (70). Another parameter, which affects the drilling time is the applied load. An inverse relationship between the square of the load and the durability of the drilling was found (48). It was established that the bone temperature rise could be the result either of the higher speed or of the higher load, but the combination of both at same time did not lead to significant heat generation (51).

CONCLUSION

The heat generation during implant site preparation could be increased by performing guided implant or piezoelectric surgery. The use of combined irrigation at higher speeds, sharper drills and laser-assisted osteotomy could help avoid the risk of thermal damage to the bone. The heat production during implant site preparation is a subject of many studies, but there is still a lack of data about temperature rise during implant insertion.

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