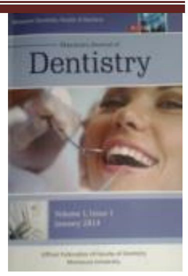

Effect of Implant Drill Speed on Bone during Implant Site Preparation (Experimental Study)

Dr. Hamdy A. M. Marzook[a], Dr. Eman Abdel Salam Yousef[b], Dr. Mona El sayed Taha Mohamed Denewar[c], Mohammed Ramadan Lotfi Farahat[d].

- [a] Assistant Professor of Oral and Maxillofacial surgery, Faculty of Dentistry, Mansoura University, Mansoura, Egypt.
- [b] Lecturer of Oral and Maxillofacial Surgery, Faculty of Dentistry, Mansoura University.
- [c] Lecturer of Oral Biology Faculty of Dentistry, Mansoura University.
- [d] Master Degree of Oral and Maxillofacial surgery, Faculty of Dentistry, Mansoura University, Egypt.

Abstract:

Background: One of the challenges that can lead to effective dental implant osseointegration is reducing surgical damage to bone tissue. The success of implant osseointegration is clearly impacted by the heat produced throughout the implant osteotomy site preparation as temperatures in the tissue of bone above $47^{O}C$ can lead to osseous necrosis. Bone necrosis of the implant bed should be prevented because of too much heat to maintain a stable osseointegration process.

Aim of the study: The objective of this experiment is to validate the impact of implant drill speed on the bone from the point of view of heat generation; a second objective is to evaluate the immediate histological viability of the bone after surgical osteotomy of bone tissue in rabbits.

Methodology: On twenty healthy adult female rabbits, this experimental trail was performed. Animals were selected for 3 bony osteotomies in the 3 mm, 3.5 mm and 4 mm diameters of the femur were made in each rabbit. Drill speed of 1000 rpm for the 3 diameters. The initial bone temperature was documented as T1 and after the last drill was recorded as T2 the highest temperature rises. After the operation the rabbits were euthanized and the bony samples were taken together for histological determination.

Results: Histological analysis demonstrates signs of bone necrosis in the form of empty lacunae near the surface of cutting, the viability of bone seems to increase with increased diameter of the drill. Furthermore, heat analysis revealed less heat produced with greater diameters compared to smaller diameters.

Conclusion: It was found in the present study that using higher speed in dense bone with presence of irrigation produces less heat and maintains more bone vitality.

Keywords: Bone viability, Drill speed, Heat generation, Rabbits.

Introduction

The restoration of missed teeth by osseointegration method with dental implants has been widely used throughout the world with high rates of accomplishment and recognized consistency [1]. The elevation of temperature throughout the preparing of the implant site is a very important factor influencing the incorporation of good osseointegrated dental implants [2]. During the preparation of the implant site and throughout its insertion, heat generated may have damaging impacts on the bone. It has already been shown that the proportion of the damaged area around on the cutting site is proportional to the generated temperature rise [3,4].

The standards of the surgical interventions have an effect on a series of phases that guide the outcome and implant main stability that is evidently the most important precondition of the finest administration of osseous integration. Thermal-permitted bone deterioration not only damage the microcirculation of the bone and reduces its regenerative capacity, but also threatens important healing and the incorporation of sensitive ossiointegration due to a reduce in the main stability of dental implants [5,6].

Previous implant studies were conducted in-vivo and in-vitro to evaluate heat generation throughout the preparation of the implant site. Scientists have demonstrated the dangerous impact of heat generation and in subsequent recovery of bone, and therefore have recognized the basic temperature that bone can sustain without damage of tissue happens, **Eriksson and Albrektsson**, [7] stated that the crucial temperature for thermal-permitted bone tissue damage is 47 °C used mostly for one minute [8].

Drilling speed is considered as an important factor that influences the output of heat [9]. Different views are separated onto the influence of the implant drill speed on the rise in temperature. It has been stated that the influence on heat generation of the drilling speed also depends on the drilling force [10]. Numerous experiments showed that a higher rate of drilling raised the shearing stress and the rubbing among the drill used and the underlying bone, resulting in an excessive rate of heat production [11].

In addition, the option of drilling speed relies on the bone's lowest heat generation and the bone's lowest exposure time at higher temperatures [12]. From the above point of view, experimental study of the influence of using varying implant drill speeds on the viability of the bone is considered necessary.

Methodology

Animals

The experimental trial was operated at Mansoura University's Medical Experimental Research Center

(MERC) using twenty healthy adult female rabbits. Animals were kept as two rabbits per cage in separate cages. Rabbits have been held in appropriate conditions such as temperature, humidity, normal rodent food.

Surgical procedures

The animals had a blend of ketamine (SEGMAT EG, 0.35 mg / kg) and xylazine (0.5 mg / kg) anesthetized intramuscular injection. In the surgical site, the lateral portion of the femur was then prepared by shaving the fur accompanied by alcohol and povidine iodine disinfection. The skin was incised on a Bard-Parker handle with blade 11 held and dissected the subcutaneous tissue all the way down to the bone. The femoral muscles are forced away from the bone with forceps. The osteotomy was performed using a drilling kit (NeoBiotech).Three implant beds were prepared in each femur segment, one in the proximal portion and the second in the central one and the third in the distal portion of the femur**.**

Grouping of animals

In osteotomies, speed 1000 rpm for the three diameters.

The preliminary bone temperature was reported as T1 and then after the last drill was measured as T2 the highest temperature rises. After surgical procedures rabbits were euthanized under the guidance of specialized veterinarians and bone specimens were obtained for histological assessment. Block specimens were deposited in formal saline instantly after 3-5 days of xylene (clearing agent) was added then and then incorporated in paraffin for 2-3 hours at 60 ° C.

Results

Heat analysis results

The mean temperature rise (ΔT) with implant drill diameter of 3 mm calculated from the difference between normal bone temperature T1 and maximum elevated temperature after the last large drill T2. The mean values and standard deviation revealed mean temperature rise (3.54 ± 0.54) **table (1).**

The temperature rise (ΔT) with implant drill diameter of 3.5 mm revealed mean temperature rise (3.14 ± 0.48) **table (2).**

The mean temperature rise (ΔT) with implant drill diameter of 4mm revealed mean temperature rise (2.60 ± 0.54) **table (3).**

Histological analysis

Vital osteocytes in their lacunae were found away from the cut surface previously prepared with implant drill of speed (1000 rpm) with drill diameter of (3 mm). Multiple empty lacunae were found near the cut surface. The cell damage was found to decrease with distance away from the cut surface **(Fig.2A).** While for 3.5 mm diameter osteotomies, the specimens showed that bone still vital by the presence of osteocytes in their lacunae, also multiple empty lacunae were found near the cut surface indicating dead cells resulting from the cutting process **(Fig. 1).** The 4 mm diameter specimens showed that bone still vital than the previous diameters, also multiple empty lacunae were found as before **(Fig. 1).**

Discussion

Various variables, such as drill shape, depth, sharpness of the cutting tool, drill speed, load applied to the drill, use of graduated versus one-step drilling, intermittent versus continuous drilling, use of internal or external irrigation, have been documented to impair the heat generation during implant preparation [13].

In this study, during the preparation of implant sites, drilling speed of 1000 rpm in the involvement of coolant were contrasted with each diameter with regard to heat generation. The temperature changes were assessed with the help of an IR thermometer. A secondary objective was to evaluate with each speed the immediate viability of the bone. Because bone necrosis is the ultimate outcome of overheating during drilling, bone vitality evaluation would be an efficient method of assessing the degree of cell injury caused by excessive heat [14].

Results of this study from speed point of view clearly show that the speed 1000 rpm has increased temperature rise in bone during osteotomy preparation with 3mm diameter in contrast to the 4mm diameter of the same speed which had the least temperature rise. In other words, by increasing the speed in the presence of coolant, the heat generation decreases. This is attributed to the fact that the greater the speed, the faster the drill reaches the desired depth of cutting and the faster return of bone to the normal temperature. Slower drilling speeds need more cutting time which produces more frictional heat.

Sharawy *et al.* [8], who studied the temperature rise using a thermocouple on fresh frozen pig alveolar bone blocks by drilling with multiple drill speeds (1225, 1667, and 2500 rpm) using external and internal cooling techniques, hypothesized that the speed of 2500 rpm produced less heat than other slower speeds. The higher speed, the less time for osteotomy preparation. They were using fresh frozen bony blocks (non-vital) placed in the heating bath and heated up to 36 °C before osteotomies, documenting higher temperatures than on living bone in the present study, as bone is the coolest body part as recorded by **Eriksson and alberketson [15].** The necrotic bone does not have the hydrodynamic blood system found in the living bone. The bone heat dissipation characteristics due to the bone vascularization system, which largely leads to heat dispersion, are hypothetically lower than the living situation.

Unlike the results of this study, **Reingewirtz *et al.* [10]** noted a positive association in the presence of an internal coolant system among the amount of temperature increase and the drill cutting speed using steel drill with various speeds varying from 0 to 10,000 rpm in dry ox femoral bone. Moreover, various elements may lead to these kinds of conflicting results as research models, drilling location, drill features, and analysis methods.

Incremental intermittent cutting for all osteotomies, intermittent burs usage allows bone chips to escape and irrigation fluid access, reducing heat generation [6,17]. When sustained drilling is done, the temperature is rising not only because of the unavailability of the cooling fluid, but also attributable to the clogging impact of the bone residue on the cutting edge of the drill, which reduces its cutting effectiveness and thus raises the time necessary for preparation of the bone bed [4]. A surgical guide was not used and the temperature assessed at the cortical bone level was shown to be affected.

Almeida *et al*. [19] stated that drilling at lower speeds would take more time to arrange the final osteotomy and therefore subject the implant's preparation site to more drilling and vibration for extended periods of time, probably leading to greater osteotomy site in size and hence lower mechanical anchorage of the implant placed in soft bone, but no clear correlation in dense bone among the speed and implant stability. It is therefore necessary to establish a good drilling protocol regarding the drilling speed.

Dental implant instant loading has been steadily conducted over the past few years. In principle, for better ossiointegration performance, a smaller necrotic zone next to an instantly loaded implant would be helpful. Because bone temperature elevations above 41 °C will raised the devitalized zone next to the cut surface after initial surgery, the concepts described here may benefit most from implants loaded before bone remodeling is finished [20,21].

There is, however, a higher rate of implant impairment in the densest forms of bone. Therefore, some differences in protocols including the speed of drilling may impair the intended result in some clinical circumstances. In this experiment, vital femoral rabbit bone was used to simulate the densest bone that could be confronted in the medical circumstance, and it was found that the higher the rpm, the lower the rise in the existence of the irrigation system. Higher drill speeds are therefore recommended for clinical application, particularly in more dense types of bone.

Different diameters have been measured in the current research. The results stated that increased drill speed with increased diameter produced less heat for the cortical bone than using a lower velocity with the same or lower diameter. Bone response to higher speed and large diameter showed no major damage to the bone particularly in comparison histologically to evaluate immediate bone viability. These findings can be attributed to the fact that the large diameter cuts less bone quantity than the initial drills so less cutting time and less production of heat [13].

The histological findings of the present study concerning immediate bone viability clearly showed that with the used implant drill speed in the current study, bone necrosis would not occur and the bone was still vital. The amount of necrotic zone adjacent to the cut surface was greater with 3m diameter in contrast to the greater diameter of 4mm.

Such findings significantly support our results in terms of heat. In this research, vital animal bone has been used to represent jaw bone, but rabbit bone is far distinct from human bone histologically with the exception of the high similarity of pig bone to human bone [22], but we have concentrated on bone vitality as a simple, available source of study.

The histological results of this study were consistent with the report by Eriksson and Adell [23] who reported that the temperature of 47 °C for 1 minute or 40 °C for 7 minutes was believed to cause necrosis in rabbit bone. The temperatures listed above did not occur with all the speeds used in our experiment and the bone was still vital with all the various speeds.

Conclusion

Under the limitation of this study, using higher speed in dense bone in the presence of coolant generate less heat and preserve more bone vitality essential for the process of osseointegration. Further investigations are needed to evaluate the performance of these speeds in humans.

References

[1] *Carvalho AC, Queiroz TP, Okamoto R, et al. Evaluation of bone heating, immediate bone cell viability, and wear of high-resistance drills after the creation of implant osteotomies in rabbit tibias. Int J Oral Maxillofac Implants. 2011;26:1193-1201.*

[2] *Watanbe F, Tawada Y, Komatsu S, et al. Heat distribution in bone during preparation of implant sites: heat analysis by real-time thermography. Int J Oral Maxillofacial Implants. 1992; 7:212–219.*

[3] *Weinlaender M. Bone growth around dental implants. Dent Clin North Am. 1991;35:585–601.*

[4] *Lamazza L, Laurito D, Lollobrigida M, et al. Identification of possible factors influencing temperatures elevation during implant site preparation with piezoelectric technique. Ann Stomatol (Roma). 2015;5:115–122.*

[5] *Yoshida K, Uoshima K, Oda K, et al. Influence of heat stress to matrix on bone formation. Clin Oral Implants Res. 2009;20:782-790."*

[6] *Strbac GD, Unger E, Donner R, et al. Thermal effects of a combined irrigation method during implant site drilling. A standardized in vitro study using a bovine rib model. Clin Oral Implants Res. 2014;25:665-674."*

[7] *Eriksson RA and Alberktsson T. The effect of heat on bone regeneration: An experimental study in rabbit using the bone growth chamber. J Oral Maxillofac Surg. 1984;42:705.*

[8] *Sharawy M, Misch C, Weller N, et al. Heat generation during implant drilling: the significance of motor speed. Journal of Oral and Maxillofacial Surgery. 2002;60(10): 1160-1169.*

[9] *Tehemar SH. Factors affecting heat generation during implant site preparation: a review of biologic observations and future considerations. Int J Oral Maxillofac Implants, 1999, 14.1: 127-136.*

[10] *Reingewirtz Y, Szmukler-Moncler S and Senger B. Influence of different parameters on bone heating and drilling time in implantology, Clin. Oral Implants Res. 1997; 189–197.*

[11] *Kalidindi V. Optimization of drill design and coolant systems during dental implant surgery M.Sc. thesis, University of Kentucky, 2004.*

[12] Lee J, Rabin Y and Ozdoganlar OB. A new thermal model for bone drilling with applications to orthopaedic surgery, Med. Eng. Phys. 2011;33:1234–1244.

[13] Eriksson RA and Adell R. Temperatures during drilling for the placement of implants using the osseointegration technique. J Oral Maxillofac Surg. 1986;44:4-7.

[14] Tabrizi R, Nazhvanai AD, Farahmand MM, Pourali SY and Hosseinpour S. Do increased drilling speed and depth affect bone viability at implant site?. Dental research journal. 2017;14(5):331.

[15] Eriksson AR and Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: a vital-microscopic study in the rabbit. J Prosthet Dent.1983;50(1):101-107.

[16] Aldabagh AH. The significance of motor speed on heat generation during implant drilling (experimental study on bovine bone). Al-Rafidain Dent. J. 2009;9:303–306.

[17] Strbac GD, Giannis K, Unger E, Mittlböck M, Vasak C, Watzek G and Zechner W. Drilling and withdrawing related thermal changes during implant site osteotomies. Clinical implant dentistry and related research. 2015; 17.1: 32-43.

[18] Penarrocha M, Garcia B, Marti E and Balaguer J. Pain and inflammation after periapical surgery in 60 patients. Journal of oral and maxillofacial surgery, 2006;64(3):429-433.

[19] Almeida K, Delgado-Ruiz R, Carneiro LG, et al. Influence of Drilling Speed on Stability of Tapered Dental Implants: An Ex Vivo Experimental Study. Int. J. Oral Maxillofac. Implants. 2016;31(4):795-798.

[20] Mishra SK. and Chowdhary R. Heat generated by dental implant drills during osteotomy-a review. The Journal of Indian Prosthodontic Society. 2014, 14.2: 131-143.

[21] Tettamanti L, Andrisani C, Bassi MA, Vinci R, Silvestre-Rangil J and Tagliabue A. Immediate loading implants: review of the critical aspects. ORAL & implantology. 2017;10(2):129.

[22] Lucchiari N, Frigo AC, Stellini E, Coppe M, Berengo M and Bacci C. In vitro assessment with the infrared thermometer of temperature differences generated during implant site preparation: the traditional technique versus the single-drill technique. Clinical Implant Dentistry. 2016;18(1):182-191.

[23] Eriksson RA and Adell R. Temperatures during drilling for the placement of implants using the osseointegration technique. J Oral Maxillofac Surg. 1986;44:4-7.

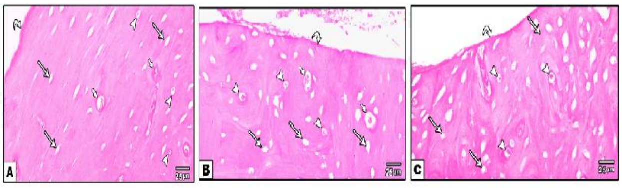

Fig. (1): Photomicrograph of the osteotomy site showing: **(A)** Drill diameter of 3 mm multiple empty lacunae (arrow) near the cut surface (curved arrow). **(B)** Drill diameter 3.5mm less empty lacunae found near the cut surface. **(C)** Drill diameter 4 mm; vital osteocytes (arrow head) near the cut surface. **H&E x400**

Table (1): Descriptive analysis of the studied cases according to amount of heat generated from implant drill in 3

Heat generated	*Group I (n = 5)*
T1	*33.00 ± 3.37*
T2	*36.54 ± 3.39*
ΔT	*3.54 ± 0.54*

Data was expressed by using mean ± SD.

Table (2): Descriptive analysis of the studied cases according to amount of heat generated from implant drill in 3.5 mm.

Heat generated	*Group II (n = 5)*
T1	*27.42 ± 1.13*
T2	*30.56 ± 1.46*
ΔT	*3.14 ± 0.48*

Data was expressed by using mean ± SD.

Table (3): Descriptive analysis of the studied cases according to amount of heat generated from implant drill in 4 mm.

Heat generated	*Group III (n = 5)*
T1	*27.20 ± 1.48*
T2	*29.80 ± 1.53*
ΔT	*2.60 ± 0.54*

Data was expressed by using mean ± SD.