

HEAT GENERATION DURING IMPLANT PLACEMENT

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Abstract: An important factor influencing implant long time survival is the atraumatic preparation of the recipient site, the bone. During bone drilling, the generated heat can be related to various factors. The present paper is classifying those factors from clinical and biological view. The methods of heat evaluation and bone examination are presented together underlining both the advantages and the shortcomings of each technique. In order to stimulate the bone growth around dental implants we should previously understand the reaction of bone to local trauma and to a variety of implant materials. The atraumatic preparation of the bone implant bed is important to obtain bone formation around the implant material.

Bone is a highly biological privileged tissue of the human body due to its richly cellular and vascular components. The bone healing after a surgical trauma such the osteotomy may take place by repair or regeneration, some authors indicating that it heals rather by regeneration than by repair, including inflammatory, proliferative and remodelling phases.(1,2)

Many attempts have been made in order to evaluate the bone heating generated by drilling the implant bed and to establish the critical thermal threshold which jeopardizes the tissue vitality predisposing to osseous necrosis.(3,4)

Still, the reported results seem to be uncertain because the previous studies used different experimental models, various approaches of heat measurement, alterable procedures of bone examination and over one hundred implant systems characterized by various armamentaria and specific indications for dental implants placement, depending on the patient factors like site, local bone density and age. Therefore, a significant increase of the various parameters involved in heat generation during the osteotomy, have occurred.

The heat generated from bone preparation during drilling was a concern during the development of osseointegrated dental implants because it prejudices the local tissue turnover. Previous papers have shown the deleterious tissue consequences involving the blood flow in capillaries (hyperemia) and bone cells degeneration resulting in fibrosis and necrosis. Of utmost harmful importance it is also the increased osteoclastic activity that facilitates the unwanted bone resorption around the newly inserted dental implant.(5,6,7)

Surprisingly, the bone is more responsive to the heat increase than it was previously supposed. There was observed that the increase of bone temperature between 44°C and 47°C did not prejudice the bony regeneration if this range of heating was not prolonged over 1 minute. However, a local heating of bone during drilling below 53°C, which is established as thermal denaturation point of a vital enzyme involved in bone turnover, the alkaline phosphatase, may be dangerous since there were also proved injurious influences regarding the regenerative potential of osteotomy site, such as the resorption of apoptotic fat cells and the slow-moving blood flow.(3,4,5,6)

At tissue level, there is an obvious discrepancy

between the living and necrotic bone considering the multitude of issues like bone cellularity and density, water content, tissue fluid movement, and thermal conductivity. The basic reason of this difference is the presence of a dynamic blood flow in living bone and the higher thermal conductivity of blood compared to that of the bone. However, the other abovementioned variables have not to be minimized since they could synergistically act to re-establish a balance when the local temperature of bone increases above the critical level.(8,9,10,11,12,13)

The various methods that can be used to record the bone heating may be classified as direct or indirect. Unlike the direct measurements that are performed by thermocouples, the indirect record is based on infrared thermography, mathematic calculation or estimation of the electrical power provided to the bur while drilling.

The thermocouple method is using heat-sensitive electrodes introduced in bone samples, attached with their free end directly to thermometers or even to more sophisticated computer software for thermal measurements.

The main limit of this system resides in its capability to identify no more than spot temperature. Moreover, other shortcomings are the technical difficulty to inserting the thermal sensors as close as possible to the drilling instrument, the heat leakage through the already performed bone perforations, and the incapability to recognize and record the overall thermal profile of drilling.

Infrared thermography is used in dentistry since 1980 as a technology relied on the revealing of energy emanated by the electromagnetic radiation. Infrared thermography enables an accurate measurement of the temperature since the emitted energy is directly correlated with the thermal effect developed by the specimens under experimental study. This technology has been used to assess the amount of heat generated during drilling for various implant systems. Previous research revealed that, unlike the thermocouple, the method of infrared thermography, is more accurate due to its ability to perform an overall appraisal of the thermal effect and to the smaller degree of error. Moreover, given that is a non-invasive method, the infrared thermography can be considered very attractive for clinical surveys.(14,15)

Commonly, the magnitude of frictional heat occurring

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during bone drilling for dental implant placement is directly proportional to the amount of pressure, diameter and design of the drill and the drilling time. However, it has to be highlighted that the main cause of bone heating is the mechanical friction developed between the bur and the wall of new alveolus site generated by drilling.(2)

1. Operator - Related Factors

1.A Pressure Applied to the Drill

The magnitude of pressure that is placed by surgeon on the handpiece and the subsequent heat generated during drilling has been not adequately investigated. Though the recorded temperature proved to be in direct relation with the drilling force it seems that the amount of the pressure hardly can be mentioned just because the force applied by operator cannot be standardized due to the unpredictability of the human factor.

The pressure exerted on the handpiece is more significant than the speed of the drill in thermal effect increase. However, it was observed a drop off of the drilling temperature while using increased pressure and higher speed, partially explained by the reduced time needed for drilling.(16)

Table no. 1. Factors Involved In Heat Generation By Drilling

1. Operator	2. Manufacturer	3. Site	4.Patient
A. Drilling pressure	A. Drill design	A. Cortical thickness	A. Age
B. Drilling status	B. Irrigation system	B. Site condition	B. Bone density
C. Drilling motions	C. Drill sharpness	C. Drilling depth	
D. Drilling speed	D. Implant system		
E. Drilling time			

1.B Gradual Versus One-step Drilling

Currently, according to the Brånemark protocol, for two stage implant insertion we gradually widen the drilling site to the almost precise diameter of the dental implant which has to be placed. Following this procedure, by using gradual series of drills depending on the implant system, the implant site is progressively widened so that, excepting the first pilot bur, only a small quantity of cortical bone is removed during surgery by each succeeding bur.

On the other hand it has to be mentioned that for a plate fixation is preferable to place the screws by using a single-twist drill, according to the procedure of one-step drilling.

In order to simplify the cutting process, save time and minimize temperature and harm risks, between the burs for gradual and the one step drilling, there are now also available on the market two step and three step drills.

1.C Intermittent Versus Continuous Drilling.

To reduce the heat generated by drilling in the bone tissue the use of irrigation, internal or external either both should be used. The irrigation solution has two main functions, to allow a continuous fluid access in the depth of osteotomy site, by flushing the bone chips, and to decrease the local temperature of bone generated during drilling by mechanical friction bur-bone.

In continuous drilling the bone overheating occurs not only because the cooling fluid does not completely penetrate simultaneously with the bur, but also because of the blockage effect of the bone debris that accumulates in the flutes of cutting edge. This compressed debris increases the mechanical friction between the bur and bone wall, leading to the decrease of drill cutting efficiency and a prolonged time for the preparation of osteotomy site.(17)

1.D Drilling Speed

Presently the importance of drilling speed is still under

debate. No significant dissimilarity between the bone healing and repair has been found while drilling with different bur speeds. However, a slow rotational speed often lessens or even limits the frictional heat arising from the bone drilling.(18,19,20) Various factors could influence the drilling speed, such as the anatomical position of drilling site of drilling, type of utilized drill, and assessment methods. Accordingly, for the time being it seems that the evidence-based recommendation would be the most appropriate. In line with the aforementioned issue it was also demonstrated that to maintain during drilling sufficient precision and minimal temperature increase, the perfect parameters for a harmless osteotomy have to be the use of low-speed but high-torque handpieces with rotational speed in the range of 1,500 and 2,000 rpm.(21,22)

1.E Time

We can consider two approaches of time: the duration of the drilling period or the duration required by the heated area of bone, situated at the bone-drill interface, in order to come back to its initial biologic temperature. Anyway, it was demonstrated that the duration of drilling is in direct relation with the amount of heat generated by rotational friction. The long-term consequence of thermal effect, while bone temperature increases up to 47°C for no more than 5 minutes, results in bone resorption after 30 days in nearly 20% of cases. Concerning the time required by overheated bone to come again to the physiological base line, it depends on the diameter and flute geometry of the drill, and the depth of osteotomy site.(2,24,25)

2. Manufacturer-Related Factors

2.A Drill Design and Flute Geometry

Nowadays, there are a lot of root-form dental implants on the market which show a great discrepancy in their design due to pertinent motivations, both biologic and mechanical. Since the final product of drilling is a new bony alveolus more or less similar in shape and diameter to the planned dental implant, in its turn is supposing as a rule that the employed drills have also to be alike to the morphology and topographic design of the root-form implant. Therefore, considering the huge diversity of implants systems available on dental market, it is demanding, if not impossible, to do a relevant comparison between drills based on their shape and flute design.

This issue is of real clinical interest since numerous studies have demonstrated the fundamental contribution of drill design and flute geometry to alveolar bone heating during the surgical drilling. Commonly, unlike the twist drills and taps that are chosen to prepare the implant bed for root-form screw-shaped dental implants, the thermal effect of triflute drills, which are indicated to be utilized in osteotomies for cylindric implants, theoretically is lower than that generated by twist drills.(2,26)

2.B Irrigation Systems

Two categories of irrigation systems are frequently utilized: internal (depending of the implant system) and external (all systems). Previous studies have shown that regularly the temperature of osteotomy site rises above the critical level to bone vitality when the drilling is performed without any irrigation. The advantages of internal irrigation over external irrigation should prevent the obstruction of drill flutes by bone debris and to preserve its efficacy irrespective of the depth of osteotomy inside the bone.(23,27) Mainly in compact bone, for any internal cooling system the use of additional external cooling seems to be extremely helpful. In that respect future studies might certify the hypothetic advantage of chilled irrigant solution to avoiding a risky bone heating.

2.C Sharpness of the Cutting Tool.

The drill sharpness plays a definite role in maintaining

the local temperature of cortical bone during drilling. Higher temperatures are expected when a worn drill is used. Previous papers showed that the drill sharpness is related to the frequency of uses, sterilization techniques, density of the osteotomy site, applied pressure by surgeon, mechanical structure of the instrument, and surface treatment of the material. The literature mentions in trephine drills substantial wear of the cutting edges after maximum 20 manipulations. Although some manufacturers recommend the maximum number of usages to preparing the osteotomy sites, the clinical experience showed the necessity of immediate bur substitution with unused one whenever the simple visual inspection discovers some deformations on cutting edges or the friction is impeding its effortless advancement inside the bone.(2,17,28)

2.D Diameter of the drill

Usually the burs of larger diameter are producing less heat than smaller ones, or compared with a 2 mm bur (pilot drill). The explanation could be that the bone quantity removed during cutting by the larger burs during gradual drilling was lower to that cut by the pilot drill or the previous drill in increasing sequence. Accordingly, using clinical sequence of burs it is simple to explain why a rotating instrument of larger diameter generates a lower degree of bone heating. Hence, it has to assume that the amount of bone to be drilled is more critical for generating bone heating than the drill size. In conclusion, to practically avoiding the local bone overheating during drilling the surgeon is obliged to carefully consider the size of initial bur utilized for osteotomy.(17,23)

3. Factors Related to the Recipient Site

3.A Cortical Thickness.

The dental implant stability is dependent of the engagement in the cortical bone. The healing of bone after the surgical insertion of a dental implant relies upon the vascular penetration, which in cancellous bone has a maximum daily rate of 0.5 mm as opposed to 0.05 mm in dense cortical bone. Hence it has to be considered the superior healing capability and thermal conduction of cancellous bone. However, mainly in the initial stages of healing the cortical bone is the key of primary implant stabilization, despite its lower vascularization rate.(27,29)

3.B Healed Versus Healing Site

Dental implants immediately placed in fresh extraction sites reduce the overall treatment duration and facilitates a quick reparative process of the extraction socket. The drilling in a healing site to placing a dental implant definitely generates a smaller thermal effect than in an already healed site of the alveolar ridge because the reduced number of burs which are used. Frequently the diameter of an extraction socket is wider than that of the dental implant to be placed. Thus, in order to create a new-alveolus the drill will go through the bone actually only in the apical segment of the socket, obviously reducing the quantity of frictional heat.(2,30,31)

3.C Drilling Depth.

Commonly the depth of the recipient site is controlled by several local factors and is 2 mm deeper than the length of the future implant. The thermal effects of drilling depth and mechanical friction are much higher in cortical bone, especially in D1 bone. Probably the nature of system used for the cooling irrigation run to a great extent the increase of bone temperature at its bone deepest point of influence, rather than the depth of the osteotomy site itself.

4. Factors Related to the Patient

4.A Age.

In the early years, the dental implants were placed initially for prosthetic rehabilitation of elderly (complete edentulism of the lower jaw). Later on their indication has been

extended to the treatment of partially edentulism of both the upper and lower jaw and single-tooth replacement, that is today most indicated. In elderly occur particular physiologic changes of the healing process. The structural components of bones are prone to become more dense and fragile, the medullary spaces of the cancellous bone broaden significantly resulting in a clear-cut thickness and mass diminution of cortical bone, and the healing potential is frequently prejudiced.

Moreover, the bone aging is also associated with an increased crystallinity of the mineral matrix owing to the enlargement of hydroxyapatite crystals and the improvement in the chemical structure of their spatial lattice.(24,32,33,34)

4.B Local bone density

Bone Density and Texture

The bone density varies from individual to individual, from one bone to another bone in the skeleton, and from a precise location to another strict location within the same bone, like upper and lower jaw. Concerning the role of bone density in explaining the drilling heat, various reports showed that the density parameter is a much more accurate marker of the temperature generated by bur than the depth of the osteotomy site itself.(35)

Biologic Observations

After drilling in the local bone, a necrotic zone starts the early stages of bone healing around the inserted dental implant. This zone will be full replaced with vital healthy bone by a reparative phenomenon dependent on the cellular and vascular status of the local bone and will continue for months around the dental implant known as osseointegration.

Further biologic studies will need clarification of the bone reactions to heat not only in testing on dead bone, or by vital surveys using thermal chambers.

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