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The effect of heating during dental implant drilling and osteonecrosis

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Abstract

Bone drilling is considered crucial in the implantation process. However, the heat generated during the drilling can lead to thermal damage and osteonecrosis. Therefore, the primary aim of this study is to assess the literature related to the effect of heating during dental drilling and the factors responsible for heat generation during the drilling procedure.

Keywords: Implant; Osteonecrosis; Heat; Drilling

1. Introduction

Drilling is considered one of the most critical and perpetually used techniques in medical science, particularly in clinical dentistry, to rebuild, reminisce or remove deformities related to hard tissues. Dental drills are helpful in creating efficient and targeted tooth drilling. During the 1950s, initial research concluded that the drill rotation during the drilling process caused an increase in temperature in neighboring tissues, direct dependency on the speed of the drilling process [1]. In addition, the friction is usually generated between the head of the drill and the bone splinters, causing a rise in heat during the drilling process. The detrimental transfer of heat of the connective tissue of bone can lead to an accumulation resulting in a constricted space [2, 3].

Bone cells are responsible for the continuous regeneration of bone tissue. Many growth and systemic factors are involved in the homeostasis of bone. RANKL is considered an essential member of the TNF (tumor necrosis factor) family [4]. Thermal osteonecrosis is a condition related to in situ cessation of bone due to excessively high temperature of tissues. The elevated speed of bone drilling plays a crucial role in osteonecrosis. There are many studies present in dental science regarding hone drilling. Albrektsson and Eriksson, in a study, concluded if the bone is exposed to a temperature of 47°C for at least one minute, it reduces the process of bone regeneration, and at 50°c impairs it [5]. While cell ceasing due to thermal damage occurs at 70°C [6]. This idea was encouraged by the study by Krause; he concluded that bone cells began to cease at a temperature of 50°C, while at 70°C, the protein regeneration stopped. Consequently, 50°C temperature is regarded as the critical value, and the temperature of bone must be kept below this [6, 7].

Drilling of bone is a crucial component of contemporary surgeries related to the musculoskeletal system and trauma. The heat generated from such operations may cause heat necrosis of bone and even tooth loss [8, 9]. Concerning recent principles of fixation of the fracture, loosening an implant of bone should be considered an issue. An inadequate amount of drilling may result in implant breaking and crippling from the fixation site. According to current literature, internal fixation has a very low failure rate [8].

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Thermal osteonecrosis is one of the significant factors associated with the deterioration of the abutment-implant interface. Osteonecrosis can be prevented by lowering the bone temperature below 50°C [6,10]. In addition, alternative drill designs, drilling parameters, and cooling procedures can help reduce heat generation. There is a large number of factors related to thermal generation. However, in the literature, only a few of them are present, which leads to consistency in obtaining the ideal combination of factors associated with reducing heat.

In addition to this, the determination of an ideal technique to measure bone temperature is difficult because the bone is a tissue composed of many organic and inorganic matters. The interaction of these matters results in complicated properties, making the tissue challenging to study because of factors such as sensitivity to biological specimen formation and conditions [11]. The usual limit of damage to the bone from high temperature is 47˚C [4-9]. Osteonecrosis occurs above this limit due to reduced blood supply and nutrients to the affected area [3].

2. Factors responsible for heat generation during dental drilling

The technique used to influence bone and the technique used to measure heat:

A large variety of drilling materials were utilized in several studies, e.g., rabbit tibia, sheep tibia, and rabbit mandible [12, 13, 14]. The Delrin Acetal was used as the drilled material to influence maxillofacial bone [15]. A recent comparison shows that bone is a better promotor of thermal conductivity [16].

A number of the method are used to measure thermal energy generated during the process of bone drilling while the placement of dental implants. Infrared thermography is one of the crucial techniques used to measure thermal energy. Another technique is also used with the help of a shielded thermocouple. These results are recorded on a digital thermometer with a microprocessor. A recent study showed that a digital thermometer is also helpful in performing thermal quantification [17, 18].

2.1. Compact Bone versus Spongy Bone

Categorization of bones can be done based on their composition, shape, and features [19]. Resistance to high heat generation during dental drilling can lead to the efficacious formation of a dental implant cavity with the least possible damage to neighboring bone [20]. The generation of heat depends on the site of the dental operation. The thermal conductivity is higher in the cortical bone because it is dense and consists of a very little amount of water as compared to bone marrow with a lower thermal conductivity rate. Spongy bone is topologically ordered and consists of water and fats. Therefore, the heat generated due to friction doesn't spread to the external surface [18, 21]. The structure and presence of blood vessels play a crucial role in the reaction obtained from bony tissue due to the heat effect. Spongy bones have the capability to scatter the heat faster due to the presence of a blood vessel network. It also has a higher capacity to regenerate as compared to compact bone. Huiskes R, in a study, found that compact bone has low thermal conductivity due to its extensive reabsorption property [22, 23].

Numerous studies have concluded that damage due to heat generation at the drilling location impedes the process of bone reestablishment and inhibits the osseointegration process. Bone is sensitive to thermal damage. Thereby temperatures above 47 °C may result in osteonecrosis. The success rate of an implant is lower in dense bone. Rhinelander, in a study, discovered that spongy bone has good regeneration capability than compact bone [18, 24, 25].

Surgical trauma results in cell alterations in bone tissue. At the beginning of the healing process, a dental implant may be related to a necrotic area due to bone drilling. However, osseointegration cannot occur in the presence of a necrotic area up to the time of replacement with a healthy bone. The initial stage of the bone healing process mainly relies on the cellular components and vascular elements of the surrounding tissues. Osteocytes play an important role in cell turnover; they can regulate the resorption of bone even after their death. De Souza Carvalho studied the effect of frequent drillings on the number of alive and dead cells. It was concluded that the extracellular matrix has a crucial role in the ossification process [18, 26, 27].

Osteoprotegerin (a protein) secreted mostly by bone cells called osteoblasts is a regulatory factor that resorbs bone and also influences tissue remodeling [28-31]. RANKL or κB is another protein that engages in bone dynamics. Osteoblasts are crucial for forming Osteocalcin (an abundant noncollagenous protein) and play a prominent role in tissue mineralization [18].

2.2. External Versus Internal Irrigation effect

Copious irrigation plays a crucial role in reducing the thermal load at the interface of bone. Watanabe et al., in their study, observed the effect of irrigation while drilling with ITI implant and other types of drills. They concluded that the heat generated with irrigation was lower than without irrigation for any drill type. Another study by Sener et al. concluded that more thermal energy was produced in the outermost part of the hole formed by the drilling process than in the innermost part. Saline with minimum temperature has more capability to cool the bone. Therefore, irrigation may be helpful during the drilling process. Benington et al. compared the effect of external and internal types of irrigation systems and found that both are equally effective. Several studies on dental implants accepted and highlighted the effectiveness of external drills for cooling [18].

3. Drill measurable factors

Drilling depth, the thickness of cortical bone, velocity of the drill, drill diameter, tension force, and drill pressure are some of the dominant drilling parameters. Drill wear is also a major parameter associated with increasing thermal energy. Matthews et al., in their study, concluded that bone temperature is directly proportional to the drill use. Allan et al. also noticed a fluctuation in temperature due to the extent of wear during porcine mandibles drilling.

Karaca et al. stated that drills coated with TiBN generate more heat as compared to uncoated drills. Li et al. created two drills with contrasting geometrical shapes to prevent heat during the drilling process. Both drills were made by utilizing superhard material. The step drill was found to generate lesser heat than the twist drill.

4. Conclusion

Many studies present in the literature conclude that heat produced by dental drilling will cause osteonecrosis. Several factors such as drill parameters, bone composition, and external and internal irrigation play a crucial role in heat generation. More studies and a good understanding of the heat generation process are required.

Compliance with ethical standards

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Disclosure of conflict of interest

All of the authors have read this manuscript, and there is no conflict of interest.

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