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Evaluation the Effect of Drill Type on Heat Generation in Implant Drilling Site

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Abstract: The purpose of this study was to compare the heat generated from implant drilling using two stainless steel and one ceramic drill. A total of 60 fresh bovine femoral cortical bone samples were used in this study. A constant drill load of 2.0 kg was applied throughout the drilling procedures via a drilling rig at a speed of 1,500 rpm. Three different implant drill types (two stainless steel and one ceramic) were evaluated. Heat was measured with type K thermocouple from 3 different depths. Data were subjected to be three way analysis of variance by newman-koolz multiple comparisons procedure. The significance level was set a priori at 0.05. The mean maximum temperature at the depths of 3, 6 and 9 mm using Drill b (Ø 4.3 ceramic drill (SPI VECTO; Thommen Medical, Waldenburg, Switzerland) were 35.7, 36.7 and 35.3°C so with Drill b mean maximum temperature was higher in 6 mm and lower in 9 mm. The mean maximum temperature at the depths of 3, 6 and 9 mm using Drill c (Ø 4.3 stainless steel (SPI VECTO; Thommen Medical, Waldenburg, Switzerland))and were 34.3, 34.4 and 33.8°C so with drill c mean maximum temperature was higher in 6 mm and lower in 9 mm. The mean maximum temperature at the depths of 3, 6 and 9 mm using Drill d (Ø 4.2 stainless steel (ITI Straumann, Basel, Switzerland)) were 34.4, 36.5 and 35.2°C so with Drill d mean maximum temperature was higher in 6 mm and lower in 3 mm. The mean maximum temperature was lowest in Drill c at 9 mm depth and it was 33.8°C and was highest for Drill b at 6 mm depth and it was 36.7°C and there was no significant difference between depths 3, 6 and 9 using different surgical drills (p = 0.056). Within the limitations of the study, although more heat was generated in the superficial part of the drilling cavity with the ceramic drill, heat modifications seemed not to be correlated with the drill type whether stainless steel or ceramic, in the deep aspect of the cavity. Further clinical studies are required to determine the effect of drill type on heat generation.

Key words: Dental implants, heat, bone, drill, osseointegration, healing

INTRODUCTION

Osseointegration has been defined as a close apposition of bone tissue at the light microscopic level with no interposition of connective or fibrous tissue at the bone/implant interface (Esposito *et al*., 1998a; Branemark *et al*., 1969).

The early failure of osseointegration may be associated with endogenous factors such as quantity and quality of bone, smoking habits and host systemic impairment such as nutritional status and bone metabolic disorders that might impair bone healing or interfere in the maintenance of osseointegration. Failure may also occur from exogenous factors such as excessive surgical trauma or surgical site infection (Esposito *et al*., 1998b) and micromovement (Eriksson and Albrektsson, 1984; Eriksson, 1984).

Preparation of hard tissues for the insertion of implants is mostly performed with cutting tools at a high speed. Cutting or drilling of bone uses energy and therefore heat is generated.

Drilling is also associated with the conversion of mechanical work energy from the friction of cutting into thermal energy which is dissipated by and causes an increase in the temperature of the surrounding cancellous and cortical (Abouzgia and Symington, 1996; Augustin *et al*., 2008; Bachus *et al*., 2000; Davidson and James, 2003; Eriksson and Albrektsson,

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1984; Franssen *et al*., 2008; Lavelle and Wedgwood, 1980; Matthews and Hirsch, 1972; Mellinger *et al*., 2003; Natali *et al*., 1996; Toews *et al*., 1999).

It seems likely that 47°C is the border temperature for the occurrence of morphologically evident bone tissue damage. The frictional heat generated by such procedures will generally give rise to a zone of devitalized bone around the bur holes or osteotomies. The extent of the necrotic zone varies exponentially with the magnitude of the temperature.

Thermal necrosis compromises healing around implants, compromises surgical procedures which depend on rigid fixation and adversely affects the healing of bone grafts (Eriksson and Albrektsson, 1983).

Generally, heat generation during implant site drilling is related to the pressure, size and shape of the drill as well as the time of drilling (Eriksson, 1984). Earlier implant studies have examined several factors including drilling speed (Albrektsson, 1980), drilling depth (Yacker and Klein, 1996; Cordioli and Majzoub, 1997; Sener *et al*., 2009), drill flute geometry (Misir *et al*., 2009), drill sharpness (Misir *et al*., 2009; Abouzgia and James, 1997), load applied to the drill (Benington *et al*., 2002) surgical drill guide (Abouzgia and James, 1997) and irrigation (Jianxin and Xing, 1997) that affect the heat generation during implant drilling. Stainless steel drills have been used successfully in implant dentistry for many years. Recently, ceramic drills were introduced with the same design features as stainless steel drills including the unique tip design for precision guided drilling. Ceramic tools have advantages such as high-temperature resistance, abrasion and corrosion resistance and low chemical affinity. However, their use is limited because of their low resistance to mechanical shock, fracture toughness and low thermal conductivity (Jianxin and Xing, 1997; Dudzinski *et al*., 2004). In the engineering literature, different ceramic tools were studied regarding their mechanism, wear behavior, cutting temperature and heat generation (Benington *et al*., 2002; Jianxin and Xing, 1997; Dudzinski *et al*., 2004; Obikawa *et al*., 1997; Da Silva and Wallbank, 1999). The temperature in the cutting zone increases because more heat is being generated and/or is concentrated in a small area and/or less heat is being dissipated (Obikawa *et al*., 1997). Therefore, the effect of the cutting conditions such as cutting speed, feed rate and depth of cut could increase the temperature having less effect are conditions such as tool geometry, material and cutting fluid (Obikawa *et al*., 1997). The purpose of this study was to compare the heat generated from implant drilling using stainless steel and ceramic drills.

MATERIALS AND METHODS

A total of 60 uniform fresh bovine femoral cortical bone samples were used in the present study. The rationale for choosing bovine cortical bones was that both human and bovine cortical bones are thermally isotropic (Krause *et al*., 1982).

All tests were performed on specimens of cortical bone from bovine femurs. Bovine bone instead of human bone was used because of the extreme difficulty in obtaining fresh human bone in the quantities required. Furthermore, bovine bone is structurally similar to human bone and its properties are well known (Robertson and Smith, 1978). Bovine femurs were obtained within 2 days of slaughter and all specimens were machined from the mid-diaphysis section of the femur (Krause *et al*., 1982).

The specimens were kept frozen until used. Heat production of three different implant drill systems-Drill b is Ø 4.3 ceramic drill (SPI VECTO; Thommen Medical, Waldenburg, Switzerland), c is Ø 4.3 stainless steel (SPI VECTO; Thommen Medical, Waldenburg, Switzerland) and d is Ø 4.2 stainless steel (ITI Straumann, Basel, Switzerland). A BEGO Paraskop M Milling machine (Model 288383, Bremen, Germany) was modified to accept a WH 985 AE handpiece. Tehemar noted that low hand pressure that usually falls in the range of 2 kg should be applied throughout the complete bony housing preparation to generate less heat (Tehemar, 1999; Eriksson and Adell, 1986). Eriksson and Adell (1986) have demonstrated that high torque, low speed handpieces running between 1,500 and 2,000 rpm are considered the ideal instruments for implant bed preparation. Based on these studies 2 kg constant load and 1,500 rpm speed for drilling were preferred in the study. So, further modification of the drill press allowed a constant load of 2.0 kg to be applied to the implant handpiece. Drill speed was maintained constant at 1,500 rpm. Drilling of the cortical bone was accomplished within the thermostat-controlled water bath. Type K thermocouples (Model 5SRTC-TT-KI-36, Omega Engineering, Manchester, UK) were used to measure temperature changes during the drilling sequence of each system. Thermocouples were read by a 3-channel, handheld data logger thermometer (Model HH147, Omega Engineering, Manchester, UK) which allowed constant, real-time temperature readings. Temperature measurements were made during site preparation with the final drill of each system. Three thermocouples were inserted vertically to the prepared sites into 1 mm holes prepared to the depths of 3, 6 and 9 mm.

RESULTS

The mean maximum temperature with Drill b was 33°C, Drill c was 32.1°C and Drill d was 32.7°C. Thermal rise was significantly lower at Drill c and was significantly higher for Drill b ($p = 0.000$). Significant correlation was between the maximum temperature of all drills ($p = 0.000$). The mean maximum temperatures at the depths of 3, 6 and 9 mm were 34.8, 35.6 and 34.5°C, respectively. The mean drilling time was 19.8 sec. Thermal rise was significantly higher at 6 mm depth ($p = 0.001$) and it was thermal rise was significantly lowest at the 9 mm depth. But there was no significant correlation between maximum temperature generated at the depths of 3 and 9 mm ($p = 0.300$). Significant correlation between the maximum temperature generated at the depths of 3, 6 and 9 mm ($p = 0.000$).

The mean maximum temperature at the depths of 3, 6 and 9 mm using drill b were 32.9, 33.3 and 32.6°C so with drill b mean maximum temperature was higher in 6 mm and lower in 9 mm. The mean maximum temperature at the depths of 3, 6 and 9 mm using Drill c were 32.1, 32.2 and 31.9°C so with Drill c mean maximum temperature was higher in 6 mm and lower in 9 mm. The mean maximum temperature at the depths of 3, 6 and 9 mm using Drill d were 32.2, 33.2 and 32.6°C so with Drill d mean maximum temperature was higher in 6 mm and lower in 3 mm. The mean maximum temperature was lowest in Drill c at 9 mm depth and it was 31.9°C and was highest for Drill b, at 6 mm depth and it was 33.3°C and there was significant difference between depths 3, 6 and 9 using different surgical drills ($p = 0.018$).

DISCUSSION

Drills used in this study were Drill b that is Ø 4.3 ceramic drill (SPI VECTO; Thommen Medical, Waldenburg, Switzerland), c that is Ø 4.3 stainless steal (SPI VECTO; Thommen Medical, Waldenburg, Switzerland) and d that is Ø 4.2 stainless steal (ITI Straumann, Basel, Switzerland). The SPI®VECTOdrill™ System* have their integrated guidance tips, according to manufacturer guidance tip provide directional and dimensional precision and The automatic axial guidance reduces drill run-off and ensures a precisely formed implant bed.

Stainless steel instrument is disposable and ceramic instrument is multi-use. The reusable SPI®VECTO drill™ ceramic drills are made from Alumina Toughened Zirconia (ATZ) for cutting performance and durability.

The Straumann® Twist Drill PRO Ø 4.2 mm is designed to help prevent over-preparation of the osteotomy site. The rounded flat-end tip facilitates safe drill positioning and ensures secure drill centering in the implant bed. The defined direction is maintained throughout the drilling process.

Ceramic tools have advantages such as high-temperature resistance, abrasion and corrosion resistance and low chemical affinity. However, their use is limited because of their low resistance to mechanical shock, fracture toughness and low thermal conductivity (Jianxin and Xing, 1997; Dudzinski *et al.*, 2004). The temperature in the cutting zone increases because more heat is being generated and/or is concentrated in a small area and/or less heat is being dissipated (Obikawa *et al.*, 1997). Therefore, the effect of the cutting conditions such as cutting speed, feed rate and depth of cut could increase the temperature having less effect are conditions such as tool geometry, material and cutting fluid.

According to Karmani (2006) the thermal conductivity of the tool material has little effect on the temperature. But according to Sumer, study is the first to evaluate heat generation using ceramic drills. The stainless steel drill tested in the study generated less heat than the ceramic drill at the depth of 3 mm. However, there was no statistical difference in heat production between these 2 drills at the depths of 6 and 9 mm. The reason for the greater heat at the depth of 3 mm might be the lower heat conductivity of ceramics than steels. Because of this low heat conductivity, localized accumulation of heat might occur in the friction zone. This is similar to the study that ceramic drill with low thermal conductivity, induced more heat generation in bone material than steel drill with same design.

The temperature in the cutting zone increases because more heat is being generated and/or is concentrated in a small area and/or less heat is being dissipated (Karaca *et al.*, 2011).

It is claimed that with increasing drilling efficacy as drilling performing faster, temperature cannot reach higher levels (Alam *et al.*, 2011).

Cutting force has axial and radial component; the sharper the drill point angle the higher is the radial component. The drill point angle has significant influence on the axial force; the sharper (more acute) the drill point angle the lower is the axial drilling force and drilling time. However, using sharper point angle as for Straumann® Twist Drill (d), drill temperature is higher on a small surface in the first moments of drilling because a relatively small percentage of cutting lip involved in cutting action.

As Straumann® Twist Drill (d) was most efficient, mean maximum temperature for ITI was highest in drill group and SPI steel drill with stalling (stop drilling) time to time had the lowest mean maximum temperature.

Maybe stalling is because of disposability or the safe end of SPI drills. It seems that stalling and lack of cutting efficacy in SPI stainless steel drill increasing with repeated drilling, didn't have influence on friction and temperature rise was lower than ceramic drill and ITI.

Actually, researchers can't compare data from different study's because of difference in type of bone and experimental conditions used. In addition while drilling, the superficial aspect of a cavity would be subjected to frictional forces for a longer time than the deeper parts of the cavity. Therefore considering duration, the deeper layers of the cavity were exposed to less friction and thus the temperature rise was significantly lower than that at shallower levels.

In bone drilling, part of the bone is removed and with the friction of the noncutting parts of the drill additional energy is released because of breaking of the intermolecular bonds (Saha *et al*., 1982).

This difference can be attributed to the fact that friction is more in 6 mm and because of irrigation is not as much as 3 mm during the preparation of the implant site in the bone as drill gradually progresses from the entrance to the bottom, the bone at the opening of the site is exposed to friction for a longer time than the one in the deeper parts.

It is logical that heat production is directly proportional to the time of exposure to frictional forces, so if the drilling procedures performed without irrigation, the thermoresistor at 3 mm was exposed to greater frictional forces than those at the other depths and it seems that the temperature chould be highest at the 3 mm depth but as drilling was with external irrigation that is more effective at shallower levels, mean maximum temperature is lowest for 9 mm, highest for 6 mm and for 3 mm depth temperature is higher than 9 but lower than 6 mm depth.

External irrigation was the chosen irrigation method in this experiment. It is obvious that irrigation was effective up to 3 mm depth because at 6 mm depth highest temperature observed and 9 mm was subjected to lower frictional forces so lowest temperature rise was in 9 mm depth. It seems that adding 4 mm sleeve height which prevents irrigation from reaching drilling site decreases irrigation efficacy and maybe in flappeles implant placement that using surgical guide sleeves is essential, 3 mm added soft tissue thickness prevent irrigation from efficiently cooling superfacial bone.

CONCLUSION

Within the limitations of the study, although more heat was generated in the superficial part of the drilling cavity with the ceramic drill, heat modifications seemed not to be correlated with the drill type whether stainless steel or ceramic, in the deep aspect of the cavity. Further clinical studies are required to determine the effect of drill type on heat generation.

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