Heat Generation on Implant Surface During Abutment Preparation at Different Elapsed Time Intervals

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Abstract: PURPOSE The purpose of this study was to evaluate heat generation at the implant surface caused by abutment preparation using a diamond bur in a high-speed dental turbine in vitro at 2 different water-coolant temperatures. MATERIALS AND METHODS Thirty-two titanium-alloy abutments were connected to a titanium-alloy implant embedded in an acrylic resin placed within a water bath at a controlled temperature of 37°C. The specimens were equally distributed into 2 groups (16 each). Group 1: the temperature was maintained at 20 ± 1°C; and group 2: the temperature was maintained at 32 ± 1°C. Each abutment was prepared in the axial plane for 1 minute and in the occlusal plane for 1 minute. The temperature of the heat generated from abutment preparation was recorded and measured at 3 distinct time intervals. RESULTS Water-coolant temperature (20°C vs 32°C) had a statistically significant effect on the implant's temperature change during preparation of the abutment ($P < 0.0001$). CONCLUSION The use of water-coolant temperature of 20 ± 1°C during preparation of the implant abutment decreased the temperature recorded at the implant surface to 34.46°C, whereas the coolant temperature of 32 ± 1°C increased the implant surface temperature to 40.94°C.

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Heat Generation on Implant Surface During Abutment Preparation at Different Elapsed Time Intervals

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ABSTRACT: (197 WORDS)

Purpose: The purpose of this study was to evaluate heat generation at the implant surface caused by abutment preparation utilizing a diamond bur in a high-speed dental turbine in vitro at two different water coolant temperatures.

Materials and Methods: Thirty-two titanium-alloy abutments were connected to a titanium-alloy implant embedded in an acrylic resin placed within a water bath at a controlled temperature of 37°C. The specimens were equally distributed into two groups (16 each). Group 1: the temperature was maintained at 20°C ± 1°C; and group 2: the temperature was maintained at 32°C ± 1°C. Each abutment was prepared in the axial plane for 1 minute and in the occlusal plane for 1 minute. The temperature of the heat generated from abutment preparation was recorded and measured at three distinct time intervals.

Results: Water coolant temperature (20°C vs 32°C) had a statistically significant effect on the implant's temperature change during preparation of the abutment ($P<0.0001$).

Conclusion: The use of water coolant temperature of 20°C ± 1°C during preparation of the implant abutment decreased the temperature recorded at the implant surface to 34.46°C while the coolant temperature of 32°C ± 1°C increased the implant surface temperature to 40.94°C.

KEYWORDS: Titanium-alloy, water bath, thermocouple

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Excessive surgical trauma is an important cause of formation of a soft tissue layer between the installed dental implant and surrounding bone tissue.[1] The extent of surgically induced bone necrosis at implant installation is mainly due to the frictional heat generated by bone cutting, although additional tissue trauma may be caused by compression or vibration. One of the factors that influence successful osseointegration is the prevention of excessive heat generation during the bone drilling procedure, or osteotomy preparation.[2] It has been concluded that bone should not be heated beyond 43°C to maintain its vitality.[3] When temperature exceeds 43°C, alkaline phosphatase begins to breakdown. Ideally, heat generation should not exceed 39°C. [3] Furthermore, Eriksson and Albrektsson[4] found that heating the bone to 47°C or 50°C for 5 minutes significantly reduced bone formation around the implants.

Osseointegration is only possible when the vitality of the bone surrounding the implant is maintained. There is no doubt that thermal damage to the bone may occur in the preparation of an implant bed (osteotomy). The extent of this damage depends on the nature and quality of the cutting tools, the speed of rotation, and whether internal or external irrigation is used during the process.[5-8]

High-speed dental handpieces can generate high levels of thermal energy. Temperature changes and thermal stress distribution in teeth resulting from high-speed tooth preparation are functions of rotation speed, type of cutting surface, force, and the nature of coolants. The use of a coolant greatly reduces the effect of heat generated regardless of the rotational speed of the bur.[9,10] A coolant applied to the bur reduces the heat generated during cutting and increases its cutting rate.[11,12] The chief purposes of the coolant are to reduce the temperature during cutting and to aid in the removal of particulate debris.[11,13] There are three types of coolants available to the dentist; air, water, and water spray (air and water combined). All three coolants can be effective in reducing the temperature during cutting.[13] The air water spray has been found to be the most effective.[14] In addition, the presence of water spray increases the cutting rate of the bur when cutting enamel compared to the cutting rate when no coolant is used.[15]

During the preparation of the implant abutment, excessive heat generation at the implant bone interface may cause irreversible bone damage and loss of osseointegration.[12,16] Bragger et al.[12] assessed in vitro the heat generation within the implant body when preparing titanium implant abutments. They found that preparation of implant abutments did not lead to detrimental effects on peri-implant tissues provided adequate cooling with spray was used. Furthermore, Gross et al.[16] examined in vitro the effects of heat generation at the implant surface caused by abutment reduction with medium extra fine grain diamond and tungsten burs in a high speed dental turbine. They found that the abutment reduction with a medium diamond using intermittent pressure and normal turbine coolant was unlikely to cause an interface temperature increase sufficient to cause irreversible bone damage or compromise osseointegration.

Aleisa et al.[17] evaluated the effect of regular and effective water flow on the heat transmission in implants caused during abutment preparation utilizing a diamond bur in a high-speed dental handpiece. They reported that increasing the water flow rate had no effect on the temperature recorded at the implant surface during abutment preparation.

Several implant prosthetic procedures could carry a risk of heat transfer to the bone-implant interface. Examples of such procedures include intra-oral preparation of implant abutments or shortening its occlusal height, sub-gingival preparation of the abutment margins, preparation of abutment grooves for resistance and retention of the final crown, shortening of impression coping screws, or occlusal adjustment of metal or porcelain restorations. Due to issues of heat transfer, sparking, and accuracy of preparation, it has been recommended that implant abutments should be prepared extra-orally, and not intra-orally.[18]

The purpose of this study was to evaluate in vitro the heat generation at the implant surface generated by abutment preparation using a diamond bur in a high-speed dental turbine handpiece utilizing two different air water coolant temperatures. The null hypothesis was that different coolant temperatures would have no effect on heat generation at implant surfaces during abutment preparations.

MATERIALS AND METHOD

Four cylindrical solid implants of 4.1 mm in diameter and 12 mm in length (Straumann® Standard implant, Institute Straumann AG, Basel, Switzerland) were used in this study. The temperature recording system was composed of J-type thermocouple electrodes (Omega Engineering Inc, Stamford, CT, USA) that were attached to a relatively flattened peripheral surface of the implant (Straumann® Standard implant) at the cervical facial aspect of its body. The tip of the thermocouple was wired tightly around the implant with another J-type thermocouple wire to ensure an intimate contact with the implant. The other end of the thermocouple was fixed to a connector (J-type, Omega Engineering Inc, Stamford, CT, USA) that was used to connect the end of the thermocouple to the temperature monitor (Thermocouple transducer, Omega Engineering Inc, Stamford, CT, USA). The implant and thermocouple were embedded in a Teflon casing (Hengshui Jinggong Rubber & Plastic Products Co., Ltd., Hengshui, Hebei, China). Silicone sealant material (GE Construction Sealants, General Electric Co., Huntersville, NC, USA) was used to seal the implant and the thermocouple tip within the Teflon casing. In such a manner, the recording system and the implant were totally isolated from any contact with the water or the acrylic block to prevent dissipation of the heat that may be transmitted through the implant body during preparation.

This assembly of implant, thermocouple and Teflon casing was then placed in a special acrylic block (Hydroplastic, Wareham, MA, USA). The acrylic-resin block was cubic in shape and 80 mm in each of the three dimensions. This acrylic block with the implant and its Teflon mount were immersed in a water bath (GFL Gesellschaft für Labortechnik mbH, Burgwedel, Germany) with a thermostatic temperature-control mechanism maintaining the starting water temperature at 37°C. A solid abutment of 5.5mm height (048.541, Institute Straumann AG, Basel, Switzerland) was inserted into the implant and torqued to 35 NCm. The abutment was isolated from the water level by a rubber dam (Hygenic dental dam latex, Coltene/Whaledent AG, Altstatten, Switzerland) tied around the implant at the cervix of the abutment (Figure 1).

To test the effectiveness and the accuracy of this temperature recording system, calibration was made by a computer program and board (Data Acquisition System, Omega Engineering Inc). The abutment of each specimen was heated to a specific known temperature and connected to the board of the computer program (Data Acquisition Program) and the temperature was recorded. Also, the recording accuracy of the monitor (Thermocouple transducer) was calibrated by connecting the same specimen of each implant at the same time to this monitor. The monitor recorded the same temperature that was recorded by the computer program and the same known temperature of the abutment. Four implants were prepared with the recording systems and acrylic blocks.

Preparation of the abutments

A high speed turbine handpiece (W&H Dentalwerk Bürmoos GmbH, Bürmoos, Austria) with a rotation speed of 390,000 rpm was used at maximum free running-speed with air pressure of 20 psi and water flow rate of 24 ml/min and every attempt was made to apply a constant pressure. The abutments were prepared using a coarse, tapered diamond instrument (No. 6836.314.014, Komet GmbH & Co. KG, Lemgo, Germany). A new diamond instrument was utilized for each specimen, and one operator performed all preparations freehand, so that the preparation technique could be regarded as reasonably consistent. Each abutment was prepared axially for 1 minute and occlusally for 1 minute. Occlusal reduction or cutting was made with a continuous force for 60 seconds and was intended to cut through the abutment and reduce its height (from the most superior aspect) by 1 mm. Axial reduction or cutting was carried out with a continuous force for 60 seconds and was intended to simulate abutment contouring. Abutments were replaced after each successive occlusal and axial reduction (cuts). A high-velocity suction tip was held 2 cm from the abutment to remove the water-coolant spray that collected on the rubber dam. In addition, a 15 minute interval was required after abutment preparation to allow the implant temperature to return to the starting temperature of 37°C. The room temperature was 37 °C ± 1°C.

Thirty-two abutments were used in this study. The specimens were equally distributed into two groups (n=16 each). Group 1: The air water coolant temperature was 20°C ± 1°C; and group 2: the air water coolant temperature was 32°C ± 1°C. The temperature of heat generation from abutment preparation was measured at three distinct time intervals. These elapsed time intervals were: (1) the temperature was recorded immediately after the end of abutment preparation (zero second); (2) the temperature was recorded 30 seconds after the end of preparation (30 seconds); (3) the temperature was recorded 60 seconds after the end of preparation (60 seconds).

Statistical analysis

Data were analyzed using a statistical software package (SPSS Software V.16, Chicago, IL, USA). Kolmogorov-Smirnov and Shapiro-Wilk tests were used to test normal distribution of the data. As the data were normally distributed, 2-way analysis of variance (ANOVA) and t-test were applied to analyze possible differences between the groups for the parameters studied. $P<0.05$ was considered to be statistically significant in all tests.

RESULTS

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Two-way ANOVA revealed that the water coolant temperatures (20°C vs 32°C) had statistically significant effects on the implant's temperature change during preparation of the abutment (P<0.0001) (Table 1). In addition, there were no significant differences between the three time intervals (P=0.693). The overall means and standard deviations (SD) of the implant's temperature at three different time intervals after the end of each cutting when the water coolant temperature was 20°C ± 1°C and 32°C ± 1°C are shown in Table 2. The mean temperature recorded immediately when the water coolant temperature was 20°C ± 1°C was 33.54°C while the mean temperature recorded when the water coolant temperature was 32°C ± 1°C was 40.94°C. This indicated a difference of about a 6.5°C higher implant temperature change recorded when the water coolant temperature was 32°C ± 1°C which was statistically significant (P<0.0001). The effect of the water coolant temperature in changing the temperature of the implant continued even after the end of preparation. This effect was determined by recording the temperature changes 30 and 60 seconds after the end of the preparation. A difference in implants temperature of 7.6°C was recorded 30 seconds after abutment preparation completion for the warmer water (P<0.0001). A difference in implants temperature of 8.1°C was recorded 60 seconds after abutment preparation completion for the 32°C ± 1°C (P<0.0001).

DISCUSSION

Measurement of temperature changes associated with the preparation of an abutment attached to an implant is complicated for two reasons. First, the thermal conductivity of titanium is lower than other materials used for dental restorations; therefore, significant temperature differences exist between the thermocouple locations and the cutting location. Second, as the cutting proceeds, the geometry changes making the temperature measurement difficult to interpret.[9]

The temperature of the water coolant itself is an effective tool in reducing the temperature during cutting. The heat generated can be dissipated by conduction through the cutting tool, by conduction through the material being cut or by the chip itself as it is removed, and by the coolant. Consequently, when the water coolant temperature is low, more heat is dissipated through this cool water, which will absorb most of the heat generated during cutting. Such dissipation of heat by the cool water spray also reduces the amount of heat absorbed by the material being cut. Another important factor in generating heat is the period of time during which the bur is applied to the subject (tooth or abutment). Intermittent cutting at intervals of a few seconds should be the rule. It has been shown that by removing the bur from the tooth intermittently for even a few seconds during crown or abutment preparation can reduce the heat generation considerably.[9,14]

The results of the study have clearly shown that cutting the implant abutment using water coolant temperature of 20°C ± 1°C will not increase the implant surface temperature from the starting temperature of 37°C but rather it will cause a decrease in the implant fixture surface temperature. Cutting the implant abutment using a water coolant temperature of 32°C ± 1°C did cause an increase in the implant fixture surface temperature which increases to 41.8°C from the starting temperature of 37°C. Therefore, the results of this study led to the rejection of the null hypothesis that the different water coolant temperatures would have no effect on heat generation at implant surfaces during abutment preparation.

It was also found that the time elapsed after the end of cutting caused changes in the implant surface temperature. The temperature decreased when the water coolant temperature was 20°C ± 1°C and increased when the water coolant temperature was 32°C ± 1°C. This difference can be explained by the fact that the heat generated during cutting had probably dissipated by conduction through the bur, by conduction through the implant abutment and implant body, and by the water coolant. Accordingly, when the water coolant temperature was low enough, most of the heat generated during cutting was dissipated. This dissipation prevented the heat from dissipating through the implant abutment and the implant body, which caused reduction in the temperature recorded on the surface of the implant. After the end of cutting, the coolant's effect continues to act on the implant abutment and the coolant's dissipation effect continues causing more change in the temperature at the surface of the implant. While heat dissipation continues after cutting, it is expected to be at a much slower rate than during cutting.

9. "Page 7 line 15 "….this cool water, which will…"
***This sentence is corrected as suggested.**

Gross et al.[16] found that cutting implant abutments for not more than 30 seconds with water coolant that had a temperature of 20°C ± 1°C caused the implant surface temperature to be around 36°C from a starting temperature of 37°C. The present study showed that cutting an implant abutment for not more than 60 seconds with water coolants that had a temperature of 20°C ± 1°C would not increase the implant surface temperature but rather it would cause a reduction in the temperature recorded from a starting temperature of 37°C. Therefore, the reduction in implant surface temperature reported in this study is significantly higher than reported by Gross et al.[16] .

Bone should not be heated beyond 43°C to maintain its vitality. Using vital microscopy, Eriksson & Albrektsson[4] observed bone tissue after exposure to 50°C for 5 minutes, 47°C for 5 minutes and 47°C for 1 minute. In the first two situations, bone was replaced by fat cells; while the exposure to 47°C for just 1 minute did not induce any changes. The authors concluded that 47°C was the maximal temperature for occurrence of morphologically evident bone tissue damage. It is known that when temperatures exceed 43°C, alkaline phosphatase begins to break down; ideally heat generation should not exceed 37°C. The in vitro set up of the present study obviously could not document reactions of cells or tissues.

Based on the above, it was concluded that cutting the implant abutment for not more than 1 minute continuously using water coolant temperature of 20°C ± 1°C and water coolant flow not less than 24 ml/min was an appropriate and safe method of implant abutment preparation. Such a procedure will not cause a harmful increase in the heat generation at the implant-tissue interface. However, should titanium implant abutments be prepared without adequate cooling, the critical temperature can be reached within only a few seconds. These findings may indicate that intra-oral preparation of abutments with warm water coolant temperature can cause temperature fluctuations of the implant body. The rise in surface temperature could then be related to potential implant complications if the heat transfer can be found to have an effect at the bone-to-implant interface. Therefore, to avoid any potential of injuring the surrounding bone, accuracy of the preparation, and other conventional prosthetic issues, it may be recommended that abutments should be prepared extra-orally rather than intra-orally.[18] Further research is needed to investigate these issues.

The study represents a preparation of a removable abutment that is being performed in a simulated situation that would represent the implant placed within the oral cavity. The problem is that within the oral cavity there will be vital tissues with circulating blood supply that is difficult to simulate in an in vitro setting. The use of warm water coolant seems to be counterintuitive while the use of room temperature water would

The preparation for one minute on the axial surface in one minute on the occlusal surface may take longer in a clinical situation as titanium is a time-consuming material to prepare. These aspects should be verified in clinical settings.

3. There are too few REFERENCES for this topic. Please be sure to give more updated and relevant REFERENCES, and be sure to rekey them within the body of your DISCUSSION, as well. This may require some renumbering of your list of REFERENCES; especially since this is not just a matter of adding to the list of REFERENCES that you currently have.

***References are updated and embedded in the discussion. References are renumbered throughout the manuscript.**

CONCLUSIONS

The following conclusions were drawn:

1. The temperature of the water coolant affected the temperature recorded at the implant surface.

2. The use of a water coolant temperature of 20°C ± 1°C during the preparation of the abutment decreased the mean temperature recorded at the implant surface to 34.46°C.

3. The use of the water coolant temperature of 32°C ± 1°C during the preparation of the abutment increased the mean temperature recorded at the implant surface to 40.94°C.

***The Conclusions are reworded and the clinical implications are emphasized.**
***The Conclusions are reworded and made more explicit.**

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DISCLOSURE: The authors declare that they have no conflict of interest.

APPROVAL: This is an In-Vitro study

role that each of these co-authors had in this project

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REFERENCES

1. Brånemark PI, Breine U, Adel R, et al. Intraosseous anchorage of dental prosthesis: I Experimental studies. *Scand J Plast Reconstr Surg.* 1969;3:81-93.

2. Albrektsson T, Brånemark PI, Hansson HA, et al. Osseointegrated titanium implants. Requirements for ensuring a long-lasting direct bone anchorage in man. *Acta Ortho Scand*. 1981;52:155-170.

3. Hobo S, Ichida E, Garcia LT. Introduction. In: Hobo S, Ichida E, Garcia LT, ed. Osseointegration and occlusal rehabilitation. Quintessence Publishing Co 1996:3-19.

4. Eriksson AR, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: A vital-microscopic study in rabbit. *J Prosthet Dent*. 1983;50:101-107.

5. Haider R, Watzek G, Plenk H. Effects of drill cooling and bone structure on IMZ implant fixation. *Int J Oral Maxillofac Implants* 1993;8:83-91.

6. Lyer S, Weiss C, Mehta A. Effects of drill speed on heat production and the rate and quality of bone formation in dental implant osteotomies. Part I: Relationship between drill speed and heat production. *Int J Prosthodont.* 1997;10:411-414.

7. Reingewirtz Y, Szmukler-Moncler S, Senger B. Influence of different parameters on bone heating and drilling time in implantology. *Clin Oral Impl Res*. 1997;8:189-197.

8. Schuchard A, Watkins C. Comparative efficiency of rotary cutting instruments. *J Prosthet Dent*. 1965;15:908-923.

9. Peyton FA. Effectiveness of water coolants with rotary cutting instruments. *J Am Dent Assoc.* 1958;56:664-675.

10. Laforgia PD, Milnao V, Morea C, et al. Temperature change in the pulp chamber during complete crown preparation. *J Prosthet Dent.* 199;65:56-61.

11. Watanabe F, Tawada Y, Komatsu S, et al. Heat distribution in bone during preparation of implant site: Heat analysis by real-time thermography. *Int J Oral Maxillofac Implants* 1992;7:212-219.

12. Bragger U, Wermuth W, Torok E. Heat generated during preparation of titanium implants of the ITT dental implant system: An in vitro study. *Clin Oral Implant Res*. 1995;6:254-259.

13. Vukovich ME, Wood DP, Daley TD. Heat generated by grinding during removal of ceramic brackets. *Am J Orthod Dentofac Orthop*. 1991;99:505-512.

14. Sarrett DC, Reitz CD. Heat generated when threaded pins are cut: A comparison of techniques. *J Prosthet Dent.* 1984;52:46-49.

15. Siegel SC, von Fraunhofer A. Irrigating solution and pressure effects on tooth sectioning with surgical burs. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 1999;87:552-556.

16. Gross M, Laufer B, Ormianar Z. An investigation on heat transfer to the implant-bone interface due to abutment preparation with high-speed cutting instruments. *Int J Oral Maxillofac Implants* 1995;10:207-212.

17. Aleisa K, Alkeraidis A, Al-Dwairi ZN, et al. Implant Fixture Heat Transfer During Abutment Preparation. *J Oral Implantol*. 2015;41:264-267.

18. Ganz SD, Desai N, Weiner S. Marginal integrity of direct and indirect castings for implant abutments. *Int J Oral Maxillofac Implants* 2006;21:593-599.

***The required information for Reference #10 is provided.**
***Discussion is expanded based on the problem of dispersion of titanium debris in the mouth.**

LEGENDS

Table 1. Summary of two-way ANOVA of main factors (water coolants and different time intervals) and their interaction for implant's temperature change.

Table 2. Implant temperature changes as influenced by the water coolant temperature when recorded at different time intervals after the end of cutting (n= 16).

Figures 1a-b. Schematic representation of experimental setup for temperature measurements after abutment preparation.

Tables:

Source	Sum of square	df	MS	F-value	P-value
Coolants	1315.276	1	1315.276	879.836	<.0001
Time	1.100	2	.550	.368	.693
Coolants x Time	10.901	2	5.450	3.646	.030
Error	134.542	90	1.495		
Total	137766.958	96			

Table 1. Summary of two-way ANOVA of main factors (water coolants and different time intervals) and their interaction for implant's temperature change. (df, Degrees of freedom; MS, mean square; p, probabilities.)

Time (seconds)	Water Coolant Temperature	Mean	SD
0	20±1°C	34.46[a]	1.52
0	32±1°C	40.94[b]	1.29
30	20±1°C	33.70[a]	1.26
30	32±1°C	41.38[b]	1.14
60	20±1°C	33.77[a]	0.92
60	32±1°C	41.83[b]	1.12

Table 2. Implant temperature changes as influenced by the water coolant temperature when recorded at different time intervals after the end of cutting (n= 16). Mean values designated with the same superscript are not significantly different (P>0.05).