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TABLE OF CONTENTS

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Thermal Changes in the Pulp Chamber during Different Adhesive Clean-up Procedures

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ABSTRACT

The aim of this in vitro study was to measure the temperature changes in the pulpal chamber when different adhesive clean-up procedures were used. Ninety intact extracted human maxillary central incisors were used in the study. The teeth were divided into six groups of 15 teeth each. The removal of the remaining composite on the tooth surface was performed with a tungsten carbide bur. The residual adhesive was removed using a high-speed handpiece with and without water cooling and a contra-angle handpiece with and without water cooling at high and low speeds. A J-type thermocouple wire was positioned in the center of the pulp chamber. The results were analyzed with analysis of variance (ANOVA) and the Tukey-honestly significant difference test. Two-factor ANOVA revealed significant interaction between the handpiece type and water cooling. In this study, the high-speed contra-angle handpiece without water cooling group had the highest ΔT values (7.58°C ± 1.84°C) among all the clean-up procedures. The decrease in pulpal temperature with water cooling was −5.34°C for the handpiece, −5.36°C for the low-speed contra-angle handpiece and −4.98°C for the high-speed contra-angle handpiece. Clinicians should be aware of the potential thermal damage to the pulp, which may result from long clean-up procedures without water cooling. Adhesive removal procedures should be performed with adequate water cooling to prevent temperature increases that might be harmful to pulpal tissues.

KEY WORDS: Clean-up, Temperature, Pulp chamber, Thermocouple.

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INTRODUCTION Return to TOC

Orthodontics has focused major attention on characterizing the residual enamel surface after various debonding procedures.[1–5] In addition, attention has been focused on the enamel loss associated with clean-up procedures.[5–7]

The possibly damaging effect of temperature increases on the pulpal tissue during dental treatment has been a matter of concern to all of dentistry.[8] Heat can be transferred to the pulp, which potentially can result in various histopathological changes such as burn reactions at the periphery of the pulp including formation of “blisters,” ectopic odontoblasts and their destruction,[9] protoplasm coagulation,[10] and expansion of liquid in the dentinal tubules and pulp, with increased outward flow from tubules. This process can affect the pulpal vessels and lead to vascular injuries with tissue necrosis.[11]

Zach and Cohen[12] reported that temperature increases of more than 5.50°C in the dental pulp produced inflammation which could not be reversed in 40% of subjects tested. They also reported that an increase of 11°C or more invariably resulted in necrosis.

Some techniques that use rotary instruments were found to generate heat and may have adverse effects on the pulpal tissues if not dissipated with an appropriate coolant.[13] Factors that influence heat generation include size and type of bur used,[14] duration of contact,[15] torque, instrument abrasiveness,[15] load,[16] and the amount of residual adhesive removed.

In operative dentistry, air-water spray cooling is essential in high-speed tooth preparation, regardless of the pressure applied or type of bur associated with the equipment.[17] Adequate cooling prevents excessive drying and promotes cutting efficiency with diamond points, steel or carbide burs.[18]

A number of clean-up techniques have been advocated in orthodontics including hand instruments,[19] sandpaper disks,[20] green rubber wheels and pumice,[19] and tungsten carbide burs.[3] The gross removal of residual composite left on the enamel surface after debonding has been reported best accomplished with a tungsten carbide bur.[3] However, limited information is available regarding the pulpal temperature changes induced by various applications of this method.

Therefore, the aim of this in vitro study was to measure the temperature changes in the pulpal chamber when different orthodontic debonding clean-up procedures were used. For the purposes of this study, the null hypothesis was that different composite removal techniques did not induce different thermal changes in the pulpal chamber.

MATERIALS AND METHODS Return to TOC

Sample preparation

Ninety intact, extracted adult human maxillary central incisor teeth were used in the study. Teeth of homogeneous size and shape were used to provide similar thicknesses of hard tooth structure and ensure equal distances from the pulp to the surface of the tooth. Pulp extensions were evaluated with radiographic films using calibrated calipers. Periapical radiographs for all teeth were made with the same X-ray unit (Siemens, 60 kV, 10 mA, Munich, Germany) with a five-cm fixed focal image distance. The radiographs were processed automatically with Periomat (Dürr Dental, GmbH & Co, Bietigheim-Bissingen, Germany). After radiographic evaluation, teeth with abnormally large or small pulp chambers were excluded from the study.

The teeth were divided into six groups of 15 teeth each. The root portions were sectioned with Carborundum disk (Komet, Gebr Brasseler, Lemgo, Germany) approximately two mm below the cementoenamel junction perpendicular to the long axis of the teeth. The opening into the pulpal chamber was enlarged as needed to insert the thermocouple wire. The pulpal chamber was cleaned of remnant pulpal tissues with a spoon excavator and NaOCl application for one minute. Then, pulp chambers of teeth were rinsed with distilled water and air dried.

All samples were etched for 30 seconds with 37% ortho-phosphoric acid (3M Dental Products, St Paul, Minn), rinsed with water from a three-in-one syringe for 30 seconds and dried with an oil-free source for 20 seconds. Metallic orthodontic brackets (Dyna-Lock series, 3M Unitek, Monrovia, Calif) (average surface area for the bracket base used was 14.00 mm^2) were then bonded with an orthodontic composite (Transbond XT, 3M Unitek). Excess composite was removed with a scaler before curing. After the composite was cured, all samples were stored in water. Brackets were removed by gently squeezing the bracket wings with pliers.

The remaining composite on the tooth surface was removed with a tungsten carbide bur under cliniclike conditions. All the procedures were performed by the same operator using special care to minimize damage to the enamel surface. The composite removal was considered complete when the tooth surface was smooth and free of composite to the naked eye under the light of the operatory lamp. The water temperature was approximately 24°C ± 2°C for all procedures using water cooling. The turbine load was set standard at 85 g. Six different clean-up procedures were used:

Group 1. A tungsten carbide bur (Komet no. H22AGK.314, Gebr. Brasseler) was operated in a handpiece at 290,000 rpm under water cooling. This high-speed handpiece (Bien Air; Chemin des Grillons, Bienne, Switzerland) with one cooling aperture (diameter = 0.7 mm) was used with an air pressure of 40 psi (~ 2.7 bar).

Group 2. A tungsten carbide bur (Komet no. H22AGK.314, Gebr. Brasseler) was operated in a handpiece at 290,000 rpm without water cooling.

Group 3. A tungsten carbide bur (Dentaurum no. 123-604, Ispringen, Germany) was operated in a contra-angle handpiece at low speed (below 15,000 rpm) under water cooling.

Group 4. A tungsten carbide bur (Dentaurum no. 123-604) was operated in a contra-angle handpiece at low speed (below 15,000 rpm) without water cooling.

Group 5. A tungsten carbide bur (Dentaurum no. 123-604) was operated in a contra-angle handpiece at high speed (above 20,000 rpm) under water cooling.

Group 6. A tungsten carbide bur (Dentaurum no. 123-604) was operated in a contra-angle handpiece at high speed (above 20,000 rpm) without water cooling.

Temperature measurement

A J-type thermocouple wire with 0.36 inch diameter (Omega Engineering, Inc, Stamford, Conn) was connected to a data logger (XR440-M Pocket Logger, Pace Scientific, Mooresville, NC, USA) during application of the clean-up procedures. All clean-up procedures and measurements were performed by the same operator to ensure uniformity in the procedures. A silicone heat-transfer compound (Philips ECG Inc, Waltham, Mass) was injected into the pulpal chamber to facilitate the transfer of heat from the walls of the pulpal chamber to the thermocouple. The thermocouple wire was put into the pulp chamber by touching the center region of the roof. Before temperature measurements were made, the position of thermocouples was verified using radiographs and corrected as needed.

The sampling rate of the data logger was set to one sample every two seconds starting with a clean-up of approximately 20–40 seconds. Calibration of the data logger was not required. Specification accuracy was maintained without user adjustment. The manufacturer reported a temperature accuracy of ±0.15°C from zero to 40°C. The collected data were monitored in real time and were transferred to a computer. The data were available in both tabular and graphic forms.

After temperature measurements, the teeth were vertically sectioned in a mesial-distal direction using a slow-speed diamond saw (Isomet; Buehler Ltd, Lake Bluff, Ill) under running water. The enamel and dentin thickness from the middle of the roof of the pulp chamber to the end of the procedure was measured with a calibrated caliper. The teeth with extremely thick or thin enamel and dentinal thicknesses were excluded from the study, and new specimens were prepared using the same procedures.

For each group, temperature variation (ΔT) was determined as the change from baseline temperature (T_0) to the highest or lowest temperature (T_{max}) recorded after various clean-up procedures. A positive ΔT value indicated an increase in pulp temperature whereas a negative ΔT value indicated a decrease in pulp temperature. Fifteen calculated temperature changes were averaged to determine the mean value in temperature rise. A temperature increase of 5.50°C was set as baseline as cited by Zach and Cohen.[12]

The test results were entered into an Excel (Microsoft, Seattle, Wash) spreadsheet for calculation of descriptive statistics. Statistical analysis was performed using an analysis of variance (ANOVA) (subsequent to confirmation of normal distribution and homogeneity of variance) and then Tukey-Honestly Significant Difference (HSD) tests (Statistical Package for Social Sciences [SPSS] Vers.10.0, SPSS, Chicago, Ill) for comparisons among groups at the 0.05 level of significance.

RESULTS Return to TOC

Data were analyzed using ANOVA and Tukey HSD tests. According to the two-factor ANOVA, a temperature rise in pulpal chamber varied significantly depending on the clean-up procedure used ($P < .001$). The null hypothesis was thus rejected. Two-factor ANOVA revealed significant interaction among the handpiece type and water cooling ($P = .000$) (Table 1). ANOVA revealed significant differences in mean values of ΔT with and without water cooling process ($P = .000$). The descriptive statistics, including the mean, standard deviation, and minimum and maximum values, for each of the six groups are presented in Table 2 (Figures 1 and 2).

The results of this study demonstrate that group 6 (high-speed contra-angle handpiece without water) had the highest ΔT values and was greater than the other clean-up procedures. In group 6, temperature increases ranged from 5.23°C to 10.14°C with a mean of 7.58°C ± 1.84°C (Figures 1 and 2).

In group 4 (low-speed contra-angle handpiece without water cooling), ΔT ranged from 2.61°C to 6.44°C with a mean of 4.27°C ± 1.28°C (Figures 1 and 2).

The results showed that the water-cooled groups (groups 1, 3, and 5) demonstrated average temperature decreases of −5.34°C ± 1.21°C, −5.36°C ± 1.62°C, and −4.98°C ± 2.22°C, respectively, during the clean-up procedure (Figures 1 and 2).

DISCUSSION Return to TOC

The present study introduced an in vitro experimental method that included investigation of some relevant parameters for orthodontic clean-up procedure with tungsten carbide bur. For this comparative study, adult central incisor teeth with similar characteristics were used to standardize the effect of enamel and dentin thickness. Central incisors were chosen because they exhibit higher risk of thermal damage because of thinner enamel and dentinal thickness on the labial side. Teeth with abnormally large or small pulp chambers were excluded from the study. This procedure was followed to eliminate possible structural variables that may manifest as differences in the thermal conductivity and specific heat. However, even after stringent selection, some differences in tooth morphology were present, and the enamel and dentinal structure and thickness were variables in this experimental design. This may explain the temperature differences between the teeth tested.[14] On the other hand, the teeth used in this study were collected from an adult sample, and therefore thermal conduction to the pulp chamber might have been limited as compared with the actual scenario in orthodontic patients who are commonly 13–16 years of age at appliance removal.

Thermocouples were selected to evaluate temperature alterations during the removal of remnant adhesive because of high precision and reliable readings demonstrated with this technique in operative and prosthetic dentistry.[12,15–18,21]

Retief and Denys[20] reported that tungsten carbide burs are most efficient for resin removal. However, carbide burs are harder than enamel[2] and, when used at high speed, can damage the underlying enamel.[2,4] Zachrisson and Årtun[3] recommended using carbide burs but at low speeds. Zarrinnia et al[5] recommended the removal of the bulk of the remaining resin with a 12-fluted tungsten carbide finishing bur, operated at high speed (above 200,000 rpm) with adequate air cooling. All these investigations were carried out to evaluate the effects of different clean-up techniques on enamel surface.

Little information about pulp chamber temperature changes associated with routinely used orthodontic techniques is available, and it usually is focused on thermal debonding. Lee-Knight et al[22] studied pulp chamber temperature increases with electrothermal debonding and found that electrothermal debonding of metal brackets without air or water coolant possibly damages the pulp. Ma et al[23] suggested that ceramic brackets can be safely debonded using a carbon dioxide laser and the intrapulpal temperature increase is within the safety threshold as reported.[12]

Trauma to the pulp and dentin during the use of rotary instrument results from several factors.[24,25] The pressure,[16] revolutions per minute,[16] bur design and type of coolant[23] influence the temperature rise and the degree of vibration. The various clinical reactions of the pulp and dentin are attributed to the interrelated factors. Schuchard[26] and Sato[27] reported that excessive heat adduction can result in structural changes to the hard dental tissues and damage the dental pulp. Zach and Cohen[12] reported that a 5.5°C rise led to necrosis of the pulp in 15% of the teeth, an 11.1°C rise resulted in necrosis of the pulp in 60% of the teeth, and a 16.6°C rise led to necrosis of the pulp in 100% of the teeth.

Robinson and Lefkowitz,[9] Taira et al,[17] and Moulding and Loney[28] all reported that cooling techniques, such as the use of an air-water spray, were effective in limiting the temperature rise in the pulpal chamber.

In the current study, all clean-up procedures with water cooling were effective in limiting the temperature rise in the pulpal chamber. Combinations of clean-up techniques under water cooling that caused ΔT not greater than 5.5°C[12] were considered safe. For all specimens without water cooling (groups 2, 4, and 6), the temperature in the pulpal chamber started increasing immediately and continuously after bur contact and steadily increased as the thickness of remaining adhesive was reduced. In groups 1, 3, and 5 with water cooling, the temperature reduced significantly after the beginning of the cooling procedure.

The results demonstrate that the specimens prepared without water cooling (groups 2, 4, and 6) demonstrated average temperature increases of 0.60°C, 4.27°C, and 7.58°C, respectively. The high-speed contra-angle handpiece technique without water cooling (group 6) caused a ΔT greater than the threshold level of 5.5°C.[12]

Despite the significant temperature increase produced by clean-up in this in vitro study, a slower or faster increase or decrease in temperature may not be relevant to actual in vivo pulpal damage. The experimental design of the present study did not consider heat conduction within the tooth due to the effect of blood circulation in the pulp chamber and fluid motion in the dentin tubules during the in vivo clean-up process.[29] In addition, the surrounding periodontal tissues can promote heat convection in vivo, limiting the intrapulpal temperature rise.[8] On the other hand, actual temperature increases might be higher in clinical conditions in younger teeth. Therefore, although this study demonstrated that most conventional clean-up techniques are safe to the pulp with regard to thermal trauma, clinicians should be aware of the potential thermal damage to the pulp that may result from long clean-up procedures without water cooling. A simple and effective way to protect the pulp is to use copious water during adhesive remnant removal.

CONCLUSIONS Return to TOC

Temperature changes in the pulpal chambers during different clean-up procedures were recorded in vitro. The following conclusions were drawn: (1) six different orthodontic clean-up procedures resulted in significant temperature changes in the pulpal chamber of extracted maxillary central incisor teeth, (2) clean-up with a tungsten carbide bur using a high-speed contra-angle handpiece without water cooling produced temperature increases exceeding the critical 5.5°C value for pulpal health, (3) procedures without water cooling significantly increased temperature in the pulpal chamber compared with procedures with water cooling, (4) clean-up with water cooling never produced temperature changes exceeding the critical value. In clinical settings, cooling procedures that use air-water sprays are essential to ensure the prevention of pulpal damage.

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TABLES Return to TOC

TABLE 1. The Results of Two-way ANOVA Performed on the Handpiece Type and Water Cooling

Source[a]	Type-III Sum of Squares	df	Mean Square	*F*	*P*
Corrected Model	1750.8	5	350.2	148.4	.000
Intercept	898.3	1	898.3	380.7	.000
A	1384.2	2	692.1	293.3	.000
B	89.3	1	89.3	37.8	.000
A × B	277.4	2	138.7	58.8	.000
Error	198.2	84	2.4		
Total	2847.3	90			
Corrected Total	1949.0	89			

[a] A: high-speed handpiece × low- and high-speed contra-angle handpiece; B: groups with water cooling × groups without water cooling.

TABLE 2. The Descriptive Statistic Values of Thermal Changes in the Pulp Chamber During Different Adhesive Clean-up Procedures[a]

	Temperature (°C)					
	N	Mean	SD	Min	Max	Test[b]
Group 1	15	−5.34	1.21	−7.39	−2.41	A
Group 2	15	0.60	1.10	−1.46	3.08	B
Group 3	15	−5.36	1.62	−8.32	−3.09	A
Group 4	15	4.27	1.28	2.61	6.44	C
Group 5	15	−4.98	2.22	−9.82	−1.91	A
Group 6	15	7.58	1.84	5.23	10.14	D

[a] Group 1: high-speed handpiece with water cooling; group 2: high-speed handpiece without water cooling; group 3: low-speed water cooling contra-angle handpiece; group 4: low-speed contra-angle handpiece without water cooling; group 5: high-speed water cooling contra-angle handpiece; group 6: high-speed contra-angle handpiece without water cooling.

[b] Groups with different letters are significantly different from each other.

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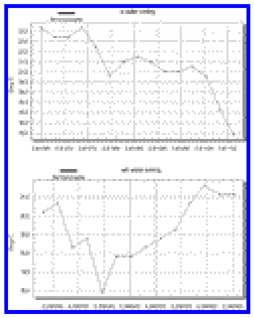
FIGURES Return to TOC



Click on thumbnail for full-sized image.

FIGURE 1. Temperature vs time graph of two representative specimens from the handpiece group with and without water cooling

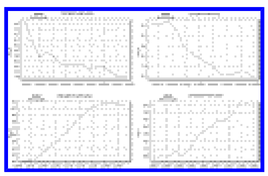


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FIGURE 2. Temperature vs time graph of four representative specimens from the contra-angle handpiece group with and without water cooling used at high and low speeds

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