ORIGINAL RESEARCH

A Comparison of Thermal Changes among Four Different Interproximal Reduction Systems in Orthodontics

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Abstract

Introduction: Interproximal enamel stripping is routinely used in orthodontics, different methods were utilized by clinicians to reduce the width of teeth but no previous study addressed the factors affecting the thermal safety of such systems on the dental pulp.

Aim: The present study was conducted to measure thermal changes among four different interproximal reduction (IPR) systems in orthodontics.

Materials and methods: A total of 130 extracted human premolar teeth were used in this study. Teeth were distributed into three experimental groups each having three subgroups and one control group. Thus, a total of 10 subgroups were created of 13 teeth each. Stripping procedures were performed using four diamond tools (burs, discs, saw, and manual strip) with different speed setup, with and without a coolant for the higher speed setup for each tool. A K-type thermocouple wire was positioned in the center of the pulp chamber and was connected to a data logger during the application of stripping procedures. Data were analyzed by the Krushkal–Wallis test using the SPSS PC+ version 21.0 statistical software.

Results: There was a highly statistically significant difference in the mean ranks of temperature values among the four groups with different speed levels. Among the 10 subgroups, the higher change in temperature registered was in the bur and disc groups when operated with the highest recommended speed without a coolant. The change in temperature was statistically significantly higher than the temperature values of other groups ($p < 0.001$). All recorded temperatures were below the critical temperature (5.5 °C) registered.

Conclusion: Based on the results of this study, IPR is a safe procedure on the dental pulp for the teeth with a medium dentin thickness with or without a coolant.

Keywords: Interproximal reduction, Orthodontic correction, Tooth.

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Introduction

Orthodontic treatment aims to give the patients good occlusion and high esthetic results in all macro/micro and mini levels. Interproximal reduction (IPR) serves in achieving these goals by managing different space requirements and managing the variations in shape and size of patients' teeth.

With a wide range of IPR applications, a number of side effects have been reported. Some of these side effects such as the surface roughness following IPR[1,2] and enamel demineralization[3] were investigated in the literature.

Moreover, the friction between the tool used for IPR and the tooth surface generates heat that might propagate to the dental pulp.[4] A histological study has proven that the critical temperature change at which dental pulp tissues will degenerate is 5.5 °C.[5]

Few researches investigated heat generation associated with the IPR procedure. Factors that could affect the amount of heat generation such as grit size of the stripping tool, speed of the motorized tools, and cooling systems were not considered. The aim of this study is to quantify the amount of temperature changes that occur in the dental pulp during interproximal stripping with different common reduction tools.

Materials and Methods

This *in vitro* experimental study consisted of 130 human premolar teeth that were indicated for the extraction for comprehensive orthodontic treatment, at the Department of Orthodontics in Riyadh Colleges of Dentistry and Pharmacy, Riyadh, KSA. An ethical approval was obtained from the research center of the institution (FPGRP/43434004/125).

Only sound human premolar teeth with the following requirements were included in this study: with no caries, no cracks/scratches in proximal surfaces under 1.2× magnifying lens, no hypoplasia, no large or provisional fillings, and patent pulp chamber (not obliterated) by evidence of X-ray.

Teeth were cleaned with normal saline and then soaked and stored in 0.1% thymol solution at room temperature. Root portions were sectioned 7 mm below cemento enamel junction (CEJ), perpendicular to the long axis with the carborundum disc. The opening to the pulp chamber through apical area was enlarged with Gates Glidden (sizes 1, 2 and 3, 4) and the remnant of soft tissues was cleaned with Endo files to facilitate injection of the thermal grease and insertion of a thermocouple probe. Pulp chambers were

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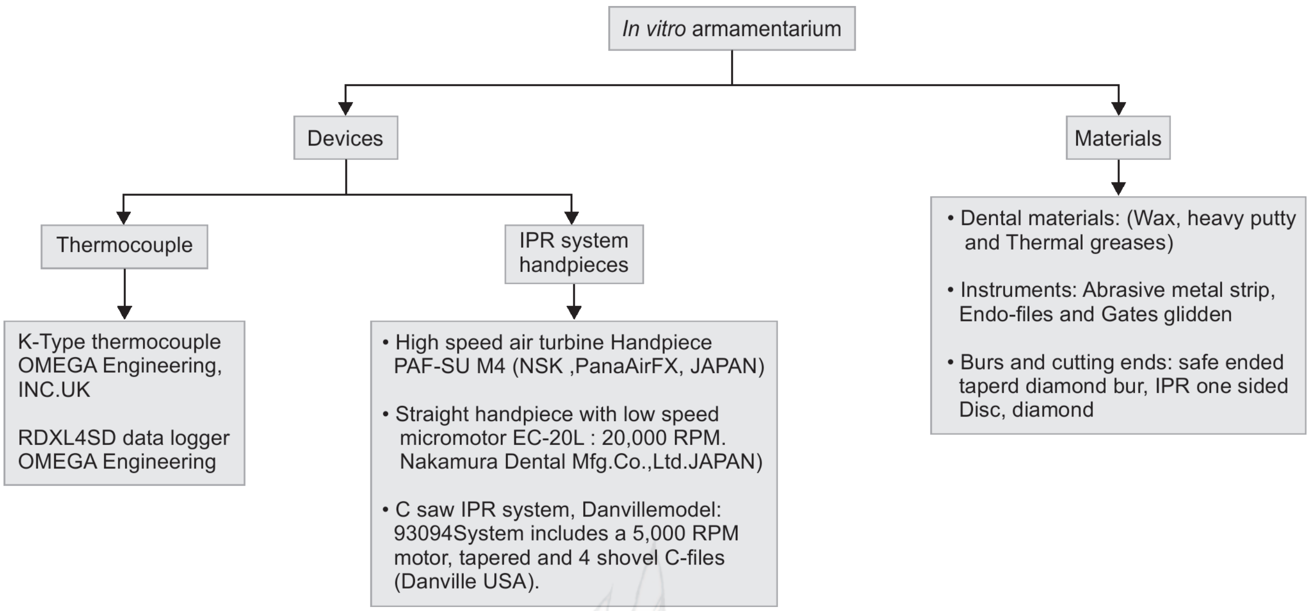
Flowchart 1: Materials and devices used in this study



rinsed with distilled water and dried with air and paper points. A total of 10 acrylic blocks were constructed which contained a horse shoe hollow within them to allow the insertion of thermocouple probes from the bottom to the root apices. Thirteen teeth were randomly mounted on the acrylic blocks in a manner that mimics their arrangement in the dental arch. Teeth were mounted initially on a small amount of flattened polysiloxane impression material (heavy putty + activator) Speedex® ColteneWhaledent. The putty and the activator were mixed and flattened at the base of the acrylic blocks, and teeth were fixed by apical thirds inserted into the putty. Wax was poured around the rest of teeth up to the cervical portion (Flowchart 1). All acrylic blocks ($n = 10$) were distributed randomly into four groups based on the IPR system, the first three groups contained three subgroups and the last group was a control group with no subgroup. Thus, 10 subgroups were of each acrylic block created. The distribution of the experimental groups into subgroups was based on the speed of the IPR system, (speed 1; S1) which was the lowest recommended speed for each system by the manufacturer, then under (speed 2; S2) which was the highest recommended speed for each system by the manufacturer without coolant, and then with a coolant under speed 2 (S2W) (Flowchart 2).

The first IPR group was the system that was safe end diamond needle bur, with a head diameter of 1.00 mm and a length of 10 mm (FG 859f010, SS White®, New Jersey, USA), operated with a high-speed air turbine handpiece. The second IPR system was a diamond disc with one-sided abrasive coating (911HH-180 RaintreeEssix, Inc. Metairie, CA, USA) operated with straight handpiece with a low-speed micromotor. The third system was the C saw IPR system, Danville model: 93094 system that includes a 5,000 rpm motor, motor to angle adaptor, reciprocal head, GP separator, 4 tapered, and 4 shovel C-files (Danville, USA). The fourth group which was the manual strip was the control.

With the range of the grit size standardized, two speed setup were used according to the manufacturers recommended range of pressure (psi). The speeds have been calculated according to the manufacturer's instructions for each handpiece with a tachometer (Table 1). Putty coverage was then removed from the bottom of each acrylic block and the teeth were filled in the retrograde direction with the GD900 thermal conductive silicone compound. The thermocouple probes being attached to a four channel data logger RDXL and two probes were inserted into two adjacent teeth in the acrylic blocks and the third one immersed in the water bath to measure the temperature of the water bath. A radiograph was taken for each of the two teeth before reduction to ensure that the probe is at the level of the pulp chamber. Then blocks were immersed in the water bath at 34–37 °C.

Pulp chamber temperature (°C) readings were obtained from a data logger for each tooth before reduction and registered as the initial temperature (T_0), by inserting the thermocouple probe inside the pulp chamber that contained thermal greases and waited for 3–5 seconds until the reading was constant. The final temperature (T_1) was obtained by registering the reading from the data logger after 20 seconds of reduction. Changes in temperature (ΔT) were calculated for the 10 experimental groups during the reduction with the handpieces operated under S1, S2, and S2W. The change of temperature was calculated as $\Delta T = T_1 - T_0$.

Data were collected and entered into the SPSS PC+ version 21.0 for statistical analysis. The nonparametric statistical test was used to compare the mean values of temperature changes among all the experimental groups with changing speeds. A comparison of the mean values of temperature changes among the four IPR systems was done. Finally, a comparison of mean values of temperature changes within each group with and without a coolant was done. A p value of <0.05 was used to report the statistical significance of results.

Prior to the main study for increasing intraexaminer reliability, 11 (n) additional premolar teeth were collected and included in the experiment. The root was sectioned below CEJ by the diamond disc, then the root orifices were enlarged and cleaned from the remnant of soft tissue by Endo-files, Gates Glidden, and irrigation and paper points, then the thermal greases were injected into the pulp chambers. The same preparation as the main study was done. Reduction with high-speed handpiece and tapered diamond bur with the same speed setup was applied and registration of

Flowchart 2: Diagram scheme for the sample distribution among the study groups and procedure

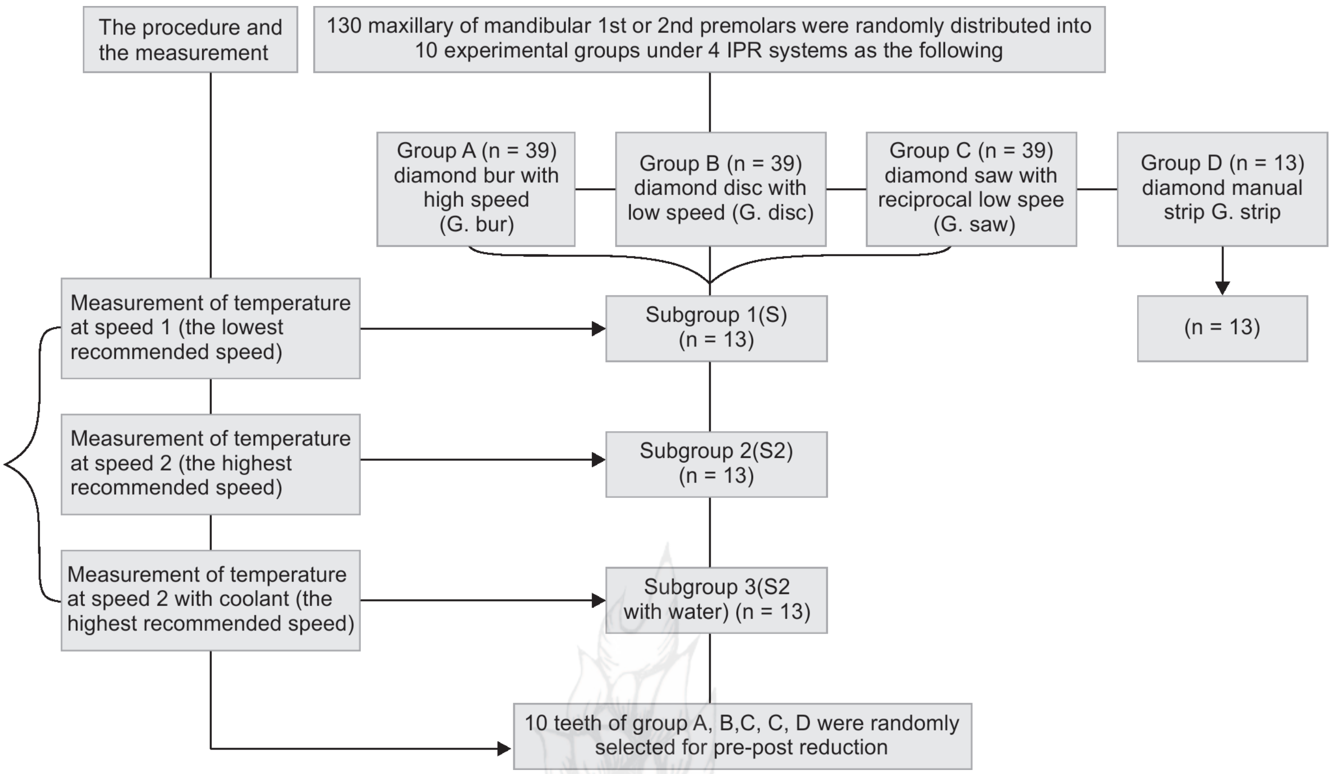


Table 1: Reduction systems with cutting heads and speeds evaluated in the study

Device/recommended pressure	*Company*	*Cutting head*	*Cutting head grit size (100–120)*	*Speed 1 (rpm)/ pressure (psi)*	*Speed 2 (rpm)/ pressure (psi)*
Manual metal strip	Komet USA, LLC Carolina, USA	–	100 µm	Manual	
High-speed handpiece/(22–30 psi)	NSK Pana Max	IPR Bur	100 µm	280,000 (22 psi)	370,000 (30 psi)
Low speed hand piece/(30–45 psi)	Nakamura Dental Mfg. Co., Ltd Japan	IPR Disc	100 µm	8,500 (30 psi)	12,000 (45 psi)
C Saw IPR kit reciprocal handpiece with 5000 RPM (35–45 psi)	Danvill USA	IPR Saw	120 µm	1,600 (35 psi)	3,000 (45 psi)

Table 2: Descriptive statistics of temperature in relation to the groups

Group	*N*	*Minimum*	*Maximum*	*Range*	*Mean*	*Std. deviation*
G.Strip	13	0.10	0.70	0.60	0.2714	0.15898
G.Bur S1	13	1.00	3.50	2.50	1.9071	0.76908
G.Bur S2	13	0.00	2.70	2.70	0.9500	0.86358
G.Bur S2W	13	–2.00	2.10	4.10	0.6643	0.93118
G.Saw S1	13	0.10	0.90	0.80	0.3643	0.28449
G.Saw S2	13	0.20	1.40	1.20	0.7571	0.40519
G.Saw S2W	13	0.00	2.00	2.00	0.4571	0.67564
G.Disc S1	13	0.50	3.00	2.50	1.3714	0.75287
G.Disc S2	13	0.30	1.90	1.60	0.7714	0.47138
G.Disc S2W	13	0.00	2.00	2.00	0.5071	0.49686
Total	130					

temperature changes before and during the reduction was done three times with 2 hours interval by using the K-type thermocouple and data logger. Data collected and statistical analysis were done to compare the results every time. No statistical differences were found.

Results

The nonparametric Kruskal–Wallis test was used to compare the influence of changing the speed from speed 1 (lower) to speed 2 (higher) within each system on the temperature changes. There was a highly statistically significant difference in the mean

Table 3: Comparison of mean ranks of temperature in relation to the speed in each of the four study groups

Groups	Mean (SD)	Mean ranks	p value
1st group			
G.Bur S1	0.75(1.0)	17.29	0.001*
G.Bur S2	1.75(1.0)	31.50	
2nd group			
G.Disc S1	0.65(0.70)	20.39	0.001*
G.Disc S2	1.20(0.90)	30.71	
3rd group		18.61	
G.Saw S1	0.25(0.30)	28.96	0.018*
G.Saw S2	0.85(0.63)	16.93	

ranks of temperature values between speeds 1 and 2 in each of the three study groups. In the three motorized IPR systems, it was found that the mean ranks of temperature are significantly higher with speed 2, when compared with the values of speed 1 (Table 3).

Table 4 shows the statistically significant difference (p value < 0.001) between the mean values of ΔT, the high-speed handpiece group (G.Bur) registered higher values while the manual metal strips registered lower values.

In Table 5, it was observed that in the first group, there was no statistically significant difference in the mean ranks of temperature between high speed with water (G.Bur.S2W) and low-speed (G.Bur.S1) samples. There was a statistically significant difference in the mean ranks of temperature between high speed with water (G.Bur S2W) and high speed 2 without water (G.Bur S2) samples, in which the mean ranks of high speed 2 without water (G.Bur S2) samples were significantly higher than the values of high speed with water (G.Bur.S2W) samples.

In the second group, there was a statistically significant difference in the mean ranks of temperature between G.Disc. S2W and G.Disc.S2 samples, in which the mean ranks of G.Disc.S2 (without water) samples are significantly higher than the values of G.Disc.S2W (with water) samples. There was no statistically significant difference in the mean ranks of temperature between G.Disc.S2W and G.Disc.S1 samples.

In the third group, there was no statistically significant difference in the mean ranks of temperature between G.Saw.S2W and G.Saw.S1 samples. There was a statistically significant difference in the mean ranks of temperature between G.Saw.S2W and G.Saw. S2 samples, in which the mean ranks of the later are significantly higher than the values of water samples (Table 5).

Overall, our results showed that there was a highly statistically significant difference in the mean ranks of temperature values among the four groups with different speed levels. Among the 10 subgroups, the higher change in temperature was registered in the bur and disc groups when operated with the highest recommended speed without a coolant.

Table 4: Comparison between the mean values of temperature changes among the inter-proximal reduction systems

Groups	Mean (SD)	F value	p value
1st group	1.43 (0.93)	10.57	<0.001*
2nd group	1.07 (0.69)		
3rd group	0.57 (0.39)		
4th group (manual strip)	0.20 (0.15)‡		

*Statistically significant; ‡significantly lower than other groups by Tukey's test

Table 5: Comparison between the mean values of temperature changes within each system with coolant without coolant

Groups	Mean	Mean ranks	p value
1st group			
(G.Bur.S2W)	0.65 (0.68)	14.21	0.854
(G.Bur.S1)	0.75 (1.0)	14.79	
(G.Bur.S2W)	0.65 (0.68)	9.0	
(G.Bur.S2)	1.75 (1.0)	20.0	<0.001*
2nd group			
(G.Disc.S2W)	0.40 (0.43)	9.07	<0.001*
(G.Disc.S1)	0.65 (0.70)	19.93	
(G.Disc.S2W)	0.40 (0.43)	11.82	0.083
(G.Disc.S2)	1.20 (0.90)	17.18	
3rd group			
(G.Saw.S2W)	0.20 (0.68)	13.18	0.401
(G.Saw.S1)	0.25 (0.30)	15.82	
(G.Saw.S2W)	0.20 (0.68)	11.25	0.035*
(G.Saw.S2)	0.85 (0.63)	17.75	

*Statistically significant

Discussion

As the IPR system became a routine procedure in dental practice, many companies introduced tools to aid and facilitate application of this procedure. The variation between these tools is not only in the shape of the cutting end and the construction material but also in the cutting method and speed as well.

In the present *in vitro* study, a comparison between four different tools in the amount of heat generation on the pulp was carried out. Human teeth (n = 130) with a medium dentin thickness (premolars) were used to evaluate the heat generated with different stripping procedures.

There are various factors which affect the amount of heat generation. Finer grit size resulted in less heat generation than coarser grit regardless of the duration of application.[6] The type of burs used could affect the temperature increase.[7] The use of high load during cavity preparation will lead to an increase in the intrapulpal temperature.[8–10] Factors that were expected to influence the heat delivered to the pulp during the conduction of the study were standardized in all groups except one parameter which is the speed. The grit size of all tools was in the range of 100–120 µm and the reduction procedure was done by the same operator to reduce the variation. The acrylic blocks were immersed in a water bath at 37 °C to mimic the oral cavity temperature. All teeth were subjected to reduction for 20 seconds. The temperature of the water of the dental unit was adjusted to 30–34 °C. In the previous studies that investigated changes in pulp temperature while performing enamel reduction, incisors, premolars, and molars were used to evaluate temperature changes in teeth with different dentin thicknesses.

In the previous studies that measured the pulp temperature during IPR, the J-type thermocouple was used, while in the present study, the K-type has been used. There is no difference in accuracy between both types. The difference is in the metal they are made of, K-type is the "general purpose" thermocouple which is made of chromel/alumel. It is of low cost, and, owing to its popularity, it is available in a wide variety of probes. It is recommended to use K-type unless there is a good reason not to. J-type (iron/constantan) has a limited range (–40 to +750 °C) that makes J-type less popular than K-type.

The thermocouple was inserted from the apical openings in the present study as well as in Baysal[5] study avoiding insertion at the crown due to its proximity to the heat source and lack of isolation.

Any tool that could be used in interproximal stripping will be applied either manually like the metal stripper or motorized like the burs, discs, saws, strips, or stripping files. In dentistry, we have two major types of handpieces: electric and air turbine handpieces. The air turbine handpieces are used more often.[11] The air turbine handpieces are classified into two types based on the number of the revolutions per minute, a high speed and a low-speed handpiece. The actual cutting speed and the rotational speed are two different aspects of high-speed turbine or air rotor handpieces. The cutting speed is usually 30% less than the rotating speed.[12] The tested range of speed depends on several factors including the torque of the handpiece which varies according to the manufacturer's specifications and the air pressure of the unit.

One study that investigated the heat generation that accompanies the stripping procedure was done under unspecific wide range of speeds.[5] The other study investigated the heat generation with low speed handpieces and manual stripping.[13]

In the present study, the different ranges of speed have been tested based on the common types available in the market and on the manufacturer's instructions. For each air turbine handpiece to work, there is a range of recommended pressure. Within this range, the operated speed varies from the lowest functioning speed to the highest. Both highest and lowest speeds recommended for both types of air turbine handpieces were tested.

The results in Table 2 showed that the ΔT registered were in the higher ranges for both G.BUR.S2 and G.DISC.S2 (3.5 °C and 3.0 °C), while the medians were 1.75 and 1.20, respectively. A higher result (7.37 °C) was obtained by Baysal et al.[5] with the tungsten carbide bur operated by a high-speed handpiece without a coolant, whereas 6.25 °C for the perforated disc operated by low-speed handpiece in premolar teeth. Readings obtained with incisors were not included in the present study. Baysal control groups (manual strip) registered higher maximum speed as well which was 2.30 °C in comparison with the highest reading obtained in the present study 0.75 °C. Similar results were registered by Perriera[13] where ΔT in the premolar group with disc operated by low-speed handpiece was 3.1 °C. Manual stripping generated higher temperature (1.90 °C) than those registered in the present study. None of the IPR groups in the present study reached the critical temperature registered by Zach and Cohen[4] which supports the findings of Pereira[13] that the IPR is a safe procedure within the recommended speed. The use of water coolant reduced the readings of intrapulpal temperature in comparison to the readings of the groups that were subjected to reduction without cooling. The water spray in the IPR will remove the furrow and will accelerate the procedure regardless of the visibility impairment.[14,15]

Limitations

Although incisor teeth have been the most common teeth to undergo enamel stripping, and due to the difficult availability of freshly extracted intact incisors, premolars were used in this study. A small sample size of 13 teeth in each 10 subgroup might also be a factor which should be considered before viewing the results.

Conclusions

Space creation for orthodontic corrections using IPR is widely used and the health of the pulp is important whenever it is performed. From the present study, it can be concluded that IPR is safe in teeth with good width of dentin irrespective of whether or not a coolant is used within the recommended speed range. Since IPR is done frequently in the anterior area, further studies that investigate temperature changes in incisors with the same speed setup of this study are recommended. Investigation of the effect of embrasure size changes in dental papilla health particularly and the health of entire periodontium is recommended.

Clinical Significance

Space creation for orthodontic corrections using IPR is widely used and several methods have been utilized. the thermal changes with those methods are within the normal tolerance of the dental pulp and a coolant is not required.

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