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RESEARCH ARTICLE

Effect of different dry-polishing regimens on the intrapulpal temperature assessed with pulpal blood microcirculation model

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Abstract

Objective: The aim of the study was to evaluate the effect of different dry-polishing regimens on the intrapulpal temperature assessed using a pulpal blood microcirculation model.

Materials and Methods: Eighty extracted human mandibular premolar teeth were used. Standardized class V cavity preparations were performed and were then restored. Teeth were divided into four main groups (n = 20): Fine polishing disc (SSF; 3M Sof-Lex, 3M ESPE, Minnesota); Super-fine polishing disc (SSS; 3M Sof-Lex); Spiral finishing wheel (SSW; 3M Sof-Lex); Enhance PoGo—One step diamond micro-polisher cup (EPO; Dentsply Sirona, Inc, Delaware). The main groups were divided: the low-load pressure (0.4N) and the high-load pressure (0.8N). The average change in intrachamber temperatures (Δt), from initial to highest, were measured.

Results: The highest temperature increase was recorded in SSF08 (9.55°C). The lowest value was recorded in EPO04 (1.9°C). SSS08, SSW08, and EPO08 demonstrated significantly higher Δt values than the low-load mode in SSS04, SSW04, and EPO04, respectively (P < .0001).

Conclusions: Temperature was the least affected by the diamond cup in both pressure modes, and it was also less affected by the spiral finishing wheel in the low-load mode than in the high-load mode. Fine and super-fine discs had the greatest effect on intrachamber temperatures.

Clinical Significance: The present study suggests intrachamber temperature can rise among different dry-polishing regimes. Dental practitioners should pay attention to dry-polishing regimens and pressures for reducing heat-related dental problems.

KEYWORDS

dental pulp, polishing methods, pulp microcirculation, pulp necrosis, pulp temperature

1 | INTRODUCTION

Caries is the most common problem encountered in hard dental hard tissues. The goal of contemporary operative dentistry is to replace the missing tissue and to maintain vitality of the tooth. After the cavity preparation stage, a restorative material is placed with an adhesive, and finishing is then performed by in the polishing phase. The temperature of dental pulp is increased by polymerization lights and frictional forces during restorative procedures. High-speed rotating systems and dental products generate heat, used in the cavity preparation stage up to the end of the polishing phase of a restoration. Increased temperatures and, therefore, physical heat transfer, may negatively affect pulp vitality.[1] Frictional forces are affected by the characteristics of the abrasive surface and the structural components of dental polishing products. Moreover, operational pressure exerted by practitioners can also cause increases in heat generation.[2]

Numerous finishing/polishing products have been used over the years, varying from multiple-step systems using fine and super-fine diamond finishing burs, abrasive discs, and diamond and silicon-filled soft rubber cups, to one-step polishing systems. Although intermittent pressure and water cooling are the most important factors in reducing the heat generation, some manufacturers report that their products can also be used without water cooling.

Sof-Lex (3M ESPE, St. Paul, Minnesota) finishing and polishing discs comprise a multistep polishing system, which includes four abrasive aluminum oxide grits ranging from coarse to super-fine. The abrasive aluminum oxides are applied to a flexible urethane-coated paper discs. Dry use of this system is recommended according to the manufacturer's instructions.[3,4]

Sof-Lex Spiral Finishing/Polishing Wheels (3M ESPE, St. Paul, Minnesota) are a part of a two-step polishing system used for final high-gloss polishing. The patented “bristle” shape has a radial bristle disc design including an elastomer impregnated with aluminum oxide particles. This is a flexible instrument that conforms to the varying topology of restoration surfaces.[5]

Enhance PoGo (Dentsply Sirona, Inc, Milford, Delaware) is a one-step polishing system. PoGo polishers are a one-step, diamond-filled, treated urethane dimethacrylate resin polishing devices manufactured for use in finishing of all composite restorations. The advantage of a one-step system is the reduction in time needed for creating a smooth surface, with no shifting to finer steps, no switching, and no washing and drying between steps.[6]

The aim of the present study was to evaluate the effect of different dry-polishing regimens on the intrapulpal temperature assessed using a pulpal blood microcirculation model. This study was also investigated the effect of loading force magnitude on intrachamber temperature. The null hypothesis tested was that the different polishing regimens would not influence increases in intrachamber temperatures of the tooth, and that different loading modes would not influence increases in intrachamber temperatures.

2 | MATERIALS AND METHODS

This study was approved by the Human Ethics Committee of the Medicine Faculty of the Medicine Faculty of Pamukkale University with reference number 60116787-020/26148.

2.1 | Sample preparation

Eighty extracted human mandibular premolar teeth, stored in 0.1% thymol, were used. Teeth with homogeneous sizes were selected. Standard periapical radiographs were acquired to calculate the distance from the pulp chamber to the outer contours of the cervical third of the crown. The teeth were divided into four main groups and two subgroups, with 10 samples in each group (Table 1).

Standardized class V cavity preparations using water cooling were performed with mean (±SD) dimensions of 3 x 4 x 2 ± 0.5 mm. The cavities were rinsed with 5 mL of distilled water; a foam pellet (Foam Pellet, Bisco, Inc, Schaumburg, IL) was used to wipe off excess water. Dentin thicknesses were left at 1.00 ± 0.05 mm between the axial wall and pulp chamber. Dentin thickness was confirmed using a universal dial gauge caliper (Heng Liang BAB700002, S/N: S1056, Shanghai, China). To avoid contamination of prepared dentinal walls, the cavity was immediately filled with a light-cured resin restoration material (A2 Body, Lot# N288820; Heraus-Kulzer GmbH, Hanau, Germany) using a two-step, self-etching adhesive system (Clearfil SE Bond, Lot # 280133; Kuraray, Inc, Osaka, Japan) and polymerized using a 1200 mW/cm^2 light-emitting diode (LED) light-curing unit (Demi Plus; Kerr Co., Middleton, Wisconsin) according to the manufacturer's instructions.

The teeth were separated horizontally using a precision diamond disc (Isomet 15 LC, Lot#110069939D16 Buehler, Illinois) 1 mm below the cemento-enamel junction. The pulpal tissues were cleaned using an excavator (17EX17; Deepeler S.A. Rolle, Swiss), and the chambers were rinsed with 5 mL of distilled water and dried with gentle stream of oil-free compressed air for 5 seconds, at the distance of 10 cm to remove excess water.

2.2 | Pulpal blood microcirculation model

A pulpal blood microcirculation model (PBMM) was configured, with slight modifications, as described in previous studies.[7–9] To introduce the thermocouple wire into the chamber, a needle-hole access was prepared on the lingual side of the teeth. A K-type thermocouple (TT-K-30-SLE; Omega Engineering, Inc, Stanford, Connecticut) was attached into the pulp chamber and placed in contact with the axial wall of the tooth using a silicone heat-transfer compound (ZM-STG2; Zalman Tech Co. Ltd, Dongan-gu, South Korea). The position of the thermocouple point was confirmed using standardized radiograpy (Proscanner; Planmeca, Inc, Helsinki, Finland) using an intraoral X-ray unit (ProX, Planmeca, Inc, Helsinki, Finland) in two directions. The exposure parameters were set according to the recommended parameters for each mandibular premolar tooth. The image plates were then scanned using a scanner (Proscanner; Planmeca). Periapical radiographic images were evaluated in a noncompressed file format (tagged image file format) using integrated viewer software (Romexis Viewer, Planmeca, Inc, Helsinki, Finland). The access cavity surrounding the thermocouple wire was filled with a light-cured flowable composite (Filtek Z350XT; 3M ESPE, Minnesota) using a two-step, self-etching adhesive system (Clearfil SE Bond; Kuraray, Inc, Osaka, Japan), and polymerized using a 1200 mW/cm^2 LED light-curing unit (Demi Plus) according to manufacturer's instructions. The wire was connected to a data logger (DT-3891G; CEM, Shenzhen, PRC), which was connected to a personal computer to monitor temperatures changes.

TABLE 1 Experimental groups with details were given below

Groups		Manufacturer	Lot #	Rpm	Load	*n*
SSF04	Sof-Lex polishing discs standard/fine 12.7 mm	3M ESPE, St. Paul, Minnesota	N747141	20 000	0.4N	10
SSF08				20 000	0.8N	10
SSS04	Sof-Lex polishing discs standard/superfine 12.7 mm		N475817	20 000	0.4N	10
SSS08				20 000	0.8N	10
SSW04	Sof-Lex spiral finishing wheels		N511339	20 000	0.4N	10
SSW08				20 000	0.8N	10
EPO04	Enhance PoGo—one step diamond micro-polisher cup	Dentsply Sirona, Inc, Milford, Delaware	662 020	20 000	0.4N	10
EPO08				20 000	0.8N	10

A custom-designed base was fabricated from a 3 mm-thick aluminum plate (1050-H14, ISO 9001:2000, Bozhong Group, Shanghai, China) for the ex vivo model configuration. According to the manufacturer's datasheet, the thermal conductivity of the plate is 222 W/m-K at 20°C. The base was drilled twice due to allow the inflow access and outflow drainage of the distilled water circulating around the enclosed pulp chamber. Each tooth sample was placed onto the holes and attached using with cyanoacrylate adhesive in each thermal test. A couple of stainless steel μ pipes (25G, Hayat Medical Co., Lot#8696569000777, Istanbul, Turkey) were placed into the holes and attached to the base using cyanoacrylate adhesive.

A digital water bath (WB-11; Daihan, Wonju, South Korea) filled with distilled water heated to a standard physiologic temperature of 37°C was used as reservoir. A digital infusion flowmeter (Outlook 100ES, B. Braun Medical, Inc, Bethlehem, Pennsylvania) was integrated into the system to stabilize the flowrate to 0.026 mL/min, a value corresponding to the physiological rate of blood flow through a pulp chamber of this volume.[10]

A pilot test was performed and the intrachamber temperature was measured to be 32 ± 1°C. Therefore, the PBMM was modified using a custom-made inflow heat stabilizer system (Figure 1). A spiral-shape copper tube was attached under the base material using a silicone heat-transfer compound. The inflow heat stabilizer apparatus was also integrated into the distilled water circulation system, which was connected to another digital infusion flowmeter (Outlook 100ES, B. Braun Medical, Inc) set to 0.026 mL/min.

Intrachamber temperature changes were measured on application of various polishing materials on the buccal aspect of the restoration. The polishing materials are listed in Table 1.

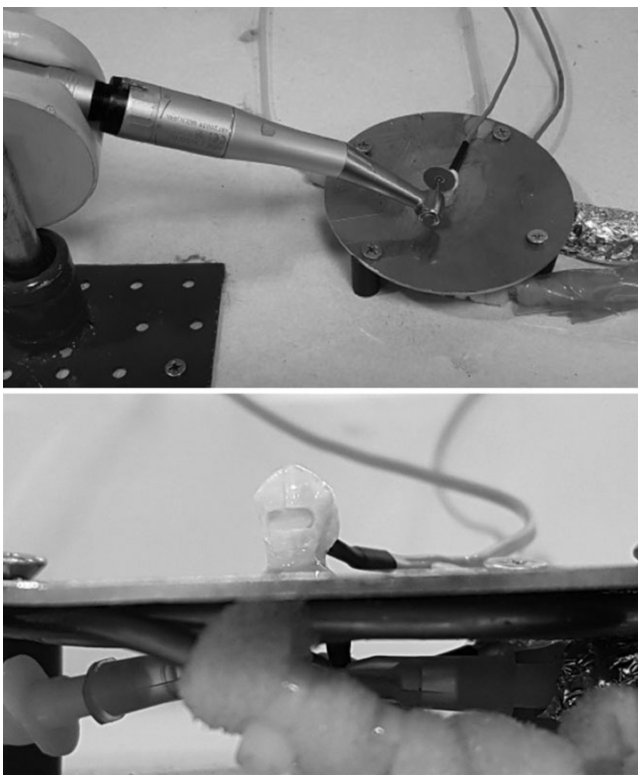

FIGURE 1 Photo of the pulpal blood microcirculation model set-up (above). The inflow water heat stabilizer system (below)

2.3 | Experimental groups

Experimental groups were as follows: Sof-Lex Polishing Discs Standard/Fine 12.7 mm at a loading force of 0.4N (SSF04); Sof-Lex Polishing Discs Standard/Fine 12.7 mm at 0.8N (SSF08); Sof-Lex Spiral Finishing Wheels at 0.4N (SSW04); Sof-Lex Spiral Finishing Wheels at 0.8N (SSW08); Enhance PoGo—One step diamond micro-polisher cup at 0.4N (EPO04); and Enhance PoGo—One step diamond micro-polisher cup at 0.8N (EPO08).

Polishing materials were used with according to the manufacturer's instructions. All groups were tested for 10 seconds at 20 000 rpm without cooling (Figure 2), in accordance with manufacturer's instructions for finishing and polishing. All the materials were activated by using a slow-speed contra angle handpiece (Mastermatic Lux M20L, KaVo Dental GmbH, Biberach, Germany) attached to an electric powered micromotor (Intra Lux KL701, KaVo Dental GmbH, Biberach, Germany). Each polishing material and each tooth sample was used only once. The handpiece was mounted on a holder connected to a fixed weight, which drove the instrument by gravity perpendicularly against the tooth sample in a precise and reproducible manner for loading. The 40 g weight (0.4N) was used as the low-load value simulating slight pressure, whereas an 80 g weight (0.8N) was used as the high-load value, simulating vigorous pressure.

The holder of the handpiece enabled precise and simple three-dimensional alignment and positioning of the polishing material against to the tooth. All tests were performed at 37°C. The average change in intrachamber temperatures (Δt), from initial to highest, were measured and were recorded using software (Multiple Data Logger, AzeoTech, Inc, Ashland, Oregon; Figure 3).

2.4 | Statistical analysis

The Shapiro-Wilk omnibus normality test revealed that data were not normally distributed. Consequently, the Kruskal-Wallis test followed by Mann-Whitney *U* multiple comparisons test was used for statistical analyses (SPSS version 23.0, IBM Corporation, Armonk, New York). The level of statistical significance was set at .0001.

3 | RESULTS

Plots confirmed that all tests were performed at 37°C. The highest temperature was recorded in the SSF08 group (9.55°C), whereas, the lowest value was recorded in EPO04 (1.9°C) after 10 seconds of dry polishing. Kruskall-Wallis analysis revealed a significant difference among the groups ($P < .0001$). Median and the minimum and maximum Δt values (°C) of the experimental groups and the number of specimens exceeding 5.6°C (threshold level) are summarized in Table 2. According to the Mann-Whithey *U* tests, significant differences among the groups were also found and summarized in Table 2.

Regardless of polishing material, high-load modes resulted in higher Δt values than low-load modes. Intragroup analysis of the polishing regimens: SSS08, SSW08, and EPO08 demonstrated significantly higher Δt values than the low-load mode in SSS04, SSW04, and EPO04, respectively ($P < .0001$).

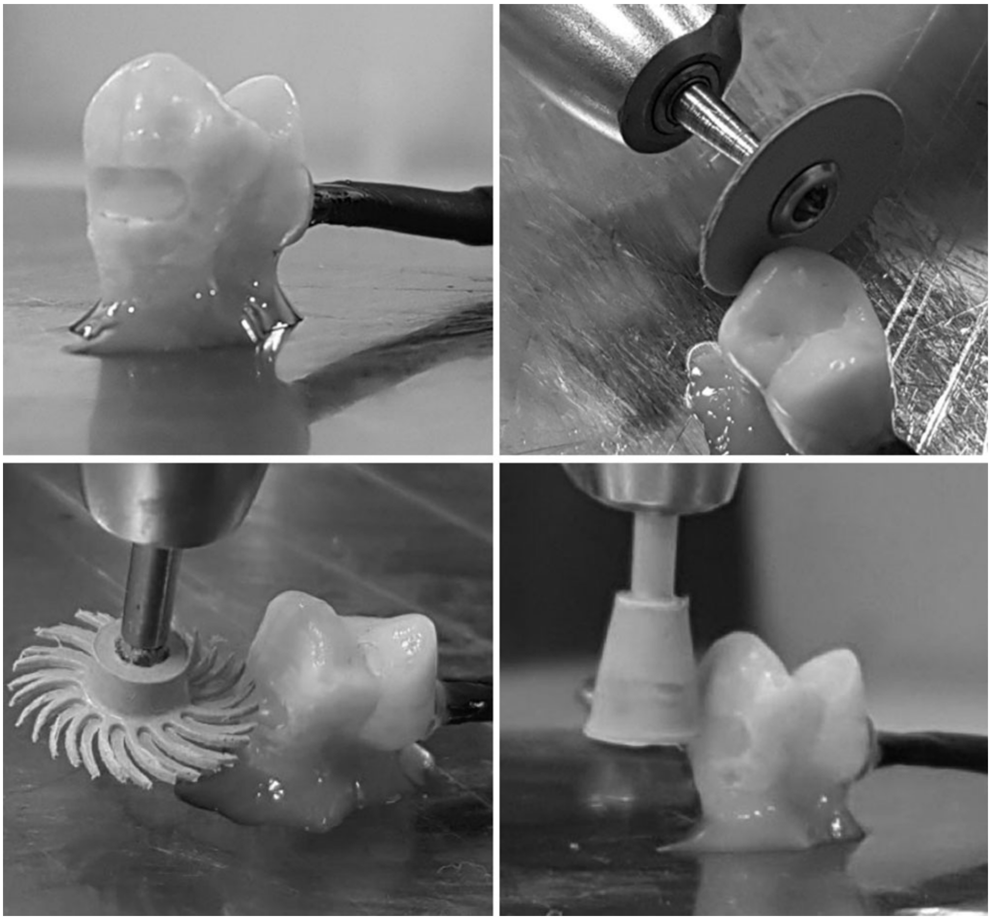

FIGURE 2 Photo of class V cavity preparation and the test materials placements

4 | DISCUSSION

Smooth restoration surfaces and sufficient marginal adaptation are critical factors for success in restorations. The achievement of smooth surfaces after appropriate finishing and polishing of composite resin restorations is clinically significant because bacterial accumulation on irregular surfaces is possible, given the correlation between bacterial adherence potentials and surface roughness.[11]

The effect of different dry-polishing regimens on the intrapulpal temperature was evaluated. The first null hypothesis was rejected because intrachamber temperature was, in fact, affected according to the dry-polishing regimen. The second null hypothesis was also rejected, given that the intrachamber temperature was affected more by the high-load mode than low-load mode.

Temperature-related pulpal damage has been reported in the literature. Intrapulpal temperature increases ≥5.6°C, causes irreversible damage to healthy pulp.[1] A reference study reported that 41.5°C is the critical limit for pulpal fibroblasts.[12] Another study reported that pulpal blood flowrate increased at temperatures >43°C, whereas irreversible damage to the microcirculation can occur if pulp temperatures exceed 49°C.[13]

Numerous ex vivo test designs have been used in similar studies. Generally, thermocouples have been attached to the pulp chamber adjacent to the cavity wall using thermal joint compounds. The tooth sample was then embedded in a water bath preheated to 37°C until the cementoenamel junction of the tooth was without microcirculation.[14–16] Some tooth temperature measurement studies have used only a single tooth in experiments.[17,18] In the present study, the PBMM was modified from previous configurations.[7–9] To simulate pulpal capillary movement, a PBMM equipped with an inflow heat stabilizer was set-up. In our preliminary tests, the 37°C water leaving the reservoir had cooled when it reached the tooth. Thus, a custom-designed inflow heat stabilizer was integrated to the system. However, there is no information about inflow heat stabilization in the microcirculation method used in other studies. To maintain the flow of water into the pulp chamber, an automatic infusion pump was integrated into the system, and microcirculation was set to a rate of 0.026 mL/min, a value that the flowrate of blood in the pulp in vivo.[8–10]

The experimental groups were based on novel finishing/polishing products available in the dental markets. According to manufacturers' instructions, the Sof-Lex fine-grit and superfine-grit discs are recommended to use dry at 30 000 rpm for 15-20 seconds.[3,4] Similarly, the Sof-Lex finishing wheel is recommended to use dry at 10 000-20 000 rpm.[5] Enhance PoGo Polishers are designed for use without water, and are recommended for use at ≤20 000 rpm.[6] There is no information regarding durations at the recommended speeds in both Sof-Lex finishing wheel and Enhance PoGo. There is also no detailed information regarding the force of application pressures in the above-mentioned instructions. Nevertheless, manufacturers recommend that light or moderate application pressures be used.[3–6]

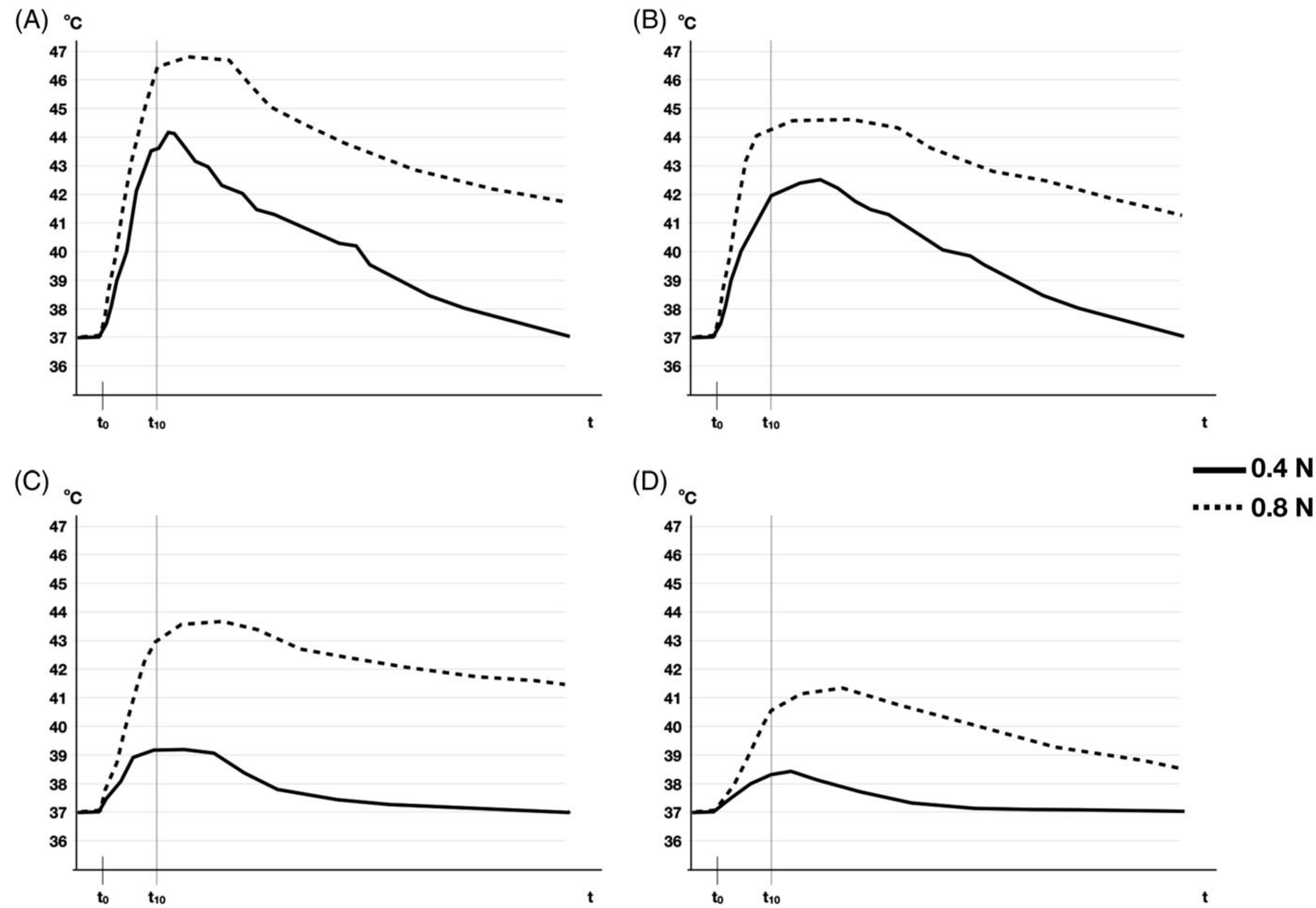

FIGURE 3 Representative temperature–time curves of the polished specimens. A, Sof-Lex polishing discs fine (SSF); B, Sof-Lex polishing discs super-fine (SSS); C, Sof-Lex spiral finishing wheels (SSW); D, enhance PoGo polisher cup (EPO). T: time, t0: start-up of the test, t10: the end of the test (10-second)

TABLE 2 Median, min., max. Δt values (°C) of the experimental groups

Groups	Median	Min.	Max.	Number of specimens exceeding 5.6°C (threshold level)
SSF04	6.75^{abcdef}	5.2	8.3	8
SSF08	9.55^{b}	7.6	10.9	10
SSS04	4.55^{c}	3.1	7.1	3
SSS08	9.3^{bd}	8.6	10.3	10
SSW04	2.25^{g}	1.8	2.6	0
SSW08	7.15^{e}	5.8	9.6	10
EPO04	1.9^{h}	1.4	3	0
EPO08	4.4^{befg}	3.3	4.7	0

Medians sharing the same letter are not significantly different (P > .05).

In the present study, constant application pressure was preferred at 20 000 rpm and 10 seconds, with no cooling strategy. Previous studies investigating the effect of application pressure(s) on intrachamber temperature have used low-[19,20] and high-load pressure values for 10 seconds.[20] However, these studies did not provide any details related to the clinical forces and finishing/polishing times. Moreover, it would have been difficult to assess the influence of these parameters in the present study because the finishing and polishing steps are not standardized among the modalities tested: Sof-Lex is a multiple-step system; Sof-Lex is are a two-step system; the Enhance PoGo is single-step system.

The data were not normally distributed. This may have been due to the small sample size of each group and/or several other variables, which may have substantially affected the experimental data and results.[21–23] The central limit theorem, as the fundamental theorem of probability, suggests that if there are a large number of variables that may affect an outcome, even if individual variables are not normally distributed, the combination of them or increasing the number of observations per group will trend toward a normal distribution.[24] Although the present study tested on 10 anatomically similar teeth in each group, different dental hard tissue characteristics may have affected intrachamber temperatures during finishing and polishing. Moreover, various in vivo conditions, such as differences in pulpal blood microcirculation,[25] thickness of dental hard tissues, and variations in dentin tubules, are difficult to standardize in in vitro studies. Consequently, this study could not directly clinically extrapolate the results. Although the in vitro study design was as standardized as possible, there were deviations among the experimental groups. Dentin is a variable and inhomogeneous substrate[26]; therefore, differences in terms of intrapulpal temperature increasing within the experimental groups may have originated from differences in dentin type. Regardless of treatment groups, more than one temperature measurement on each tooth would be expected to yield more reliable results to ensure the reproducibility; however, this is not clinically relevant due to the above-mentioned variable characteristics of dentin.

The highest temperature is mostly responsible for the predictable pulpal reaction in the worst cases. The diamond cup and spiral wheel in the low-load mode generated median average temperature increases of 1.9 and 2.25°C, respectively which is less likely to cause a clinically relevant pulp reaction. However, a temperature increase *t* of 7.15°C was recorded the high-load mode using the spiral wheel. This may be explained by the squeezing of the spirals into the core of the spiral wheel which, in turn, increased frictional forces on the tooth surface. The diamond polishing cup yielded the lowest average temperature values. This was probably due to the minimum contact surface area of the cup and the surface; therefore, frictional forces could not increase the temperature in either of the load modes.

The highest average temperatures were measured using finishing/polishing discs in both load modes. In particular, median values were above the critical limit of intrapulpal temperature, which may increase the risk for irreversible pulp damage in the high-load mode. Because the abrasive surface of the disc has a large contact area with the surface of the restoration, wear of the abrasive grain may have caused the generation and transmission of heat energy onto the surface in a shorter time than in the other groups.

The diamond cup in both load modes generated low average temperature changes after 10 seconds. However, the spiral wheel generated intrachamber temperatures >42°C in the high-load mode. The manufacturer of the Sof-Lex polishing discs recommends speeds up to 30 000 rpm without water-cooling. Our results demonstrated that intrachamber temperature had the highest values using this polishing method with polishing discs in both load modes at 20 000 rpm. Thus, if these polishing regimens are to be used at the finishing stage of the restoration of deep cavities, they must be used under intermittent pressures and cooling. Although water is recommended to prevent overheating, some manufacturers of the products tested in the present study recommend dry polishing. Therefore, a control group consisting of a cooling strategy was not included in the experiments. Different rotational speeds and intermittent pressure, and/or any cooling methods, to assess the intrapulpal heat changes during polishing can be incorporated into similar further studies.

5 | CONCLUSION

Within the limitations of this study, several conclusions can be drawn. Intrachamber temperature was least affected by the diamond cup in both pressure modes and was also less affected by the spiral finishing wheel in the low-load mode than in the high-load mode. Nevertheless, fine and super-fine discs had the greatest effect on intrachamber temperatures.

DISCLOSURE

The authors do not have any financial interest in any companies whose products are included in this article.

ETHICAL APPROVAL

This study was approved by the Human Ethics Committee of the Medicine Faculty of Pamukkale University (Denizli, Turkey) with reference number 60116787-020/26148.

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