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Root Dentin Strain and Temperature Rise During Endodontic Treatment and Post Rehabilitation

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This study investigated the effects of endodontic treatment procedures and different post systems rehabilitation steps on the strain and temperature rise on apical and cervical root dentin regions. Twenty-one extracted human canine teeth had two strain gages attached to the distal root surface and two thermocouples attached to the mesial root surface (cervical and apical). The strain and temperature rise were recorded during the following procedures: root canal preparation, final rinse and drying, root canal filling and canal relief. Then the teeth were divided into three groups (n=7), according to the type of post system: CPC, cast post and core; FGP, fiberglass post; and PSP, prefabricated steel post. Data continued to be recorded during the post space preparation, post modeling (only for CPC), post trying and post cementation. Data were subjected to a two-way ANOVA followed by Tukey's test (α=0.05). The post-space preparation caused the highest temperature rise (4.0-14.9 °C) and the highest strain in the apical region during irrespective of post type. The resin cement light-activation resulted in significant temperature increases in the cervical region for all of the groups. The canal relief and the post-space preparation produced highest temperature rises. The CPC post modeling resulted in higher root strain level similarly the level of post preparation. The PSP resulted in highest strain during post trying and post cementation.

Key Words: cast post and core, fiberglass post, deformation, prefabricated steel post, root filled teeth, strain gage test, temperature.

Introduction

With the development of endodontic therapy, the recovery and maintenance of severely damaged teeth became possible (1). For teeth with minimal coronal structure, a post is indicated to retain and improve the distribution of the functional loads to the root (2). The endodontic therapy and post and core rehabilitation change the normal stress and strain distribution patterns inside the teeth (3), reducing the resistance to fracture (4). Endodontic therapy involving root canal preparation, obturation and lateral condensation, canal relief, post-space preparation and post cementation could produce thermo-mechanical alterations to root-filled teeth (5,6). These procedures may damage the tooth structure and the surrounding supportive structure; tooth ankylosis or bone necrosis and resorption are also possible outcomes (7,8). Additionally, dentin root strain is generated at the same time as the heat production and may be a main or contributing cause of vertical root fracture (5).

High temperature levels may damage the bone tissue. The inactivation of bone alkaline phosphatase has been associated with high temperatures, around 56 °C (9). Another study reported that bone tissue was sensitive to heat at 47 °C (8). It has also been reported that a 1-min exposure to a 53 °C temperature may result in blood flow interruption in the bone (10). Exposing the periodontal ligament to a 43 °C temperature may result in protein denaturation (11). However, it is generally agreed that 10 °C is the critical temperature increase at which damage may occur to tooth support tissues (7,12).

In recent years, rotary nickel-titanium (Ni-Ti) instruments have allowed much improvement in endodontic canal preparation. In addition to being faster, Ni-Ti instruments are known to be more flexible and allow maintaining root canal preparation to be more centered and better tapered, create fewer procedural errors than stainless steel instruments (13,14). The speed of the instruments inside the root canal also interferes in heat production and its transmission to the external surface since heat is directly proportional to speed (15). Different post systems could generate different amounts of heat and strain on the root surface.

The amount of heat and dentin strain that is generated during the rehabilitation process has been quantified using *in vitro* studies (5,12,16). However, no studies have measured the strain and temperature rise on the root dentin external surface in real time (from the beginning of endodontic treatment to the end of the post space cementation). Therefore, the aim of this study was to test two hypotheses: first, that the temperature rise and dentin strain generated during endodontic treatment differ in each root surface region and among the different endodontic procedures; second, that the post system influences the temperature rise and dentin strain produced during the post rehabilitation.

Material and Methods

The research protocol was approved by the Federal University of Uberlândia Ethics Committee (Process #396/2010). Twenty-one freshly extracted human maxillary canines, with roots anatomically similar in size and shape were selected after measurement of the buccolingual and mesiodistal widths in millimeters, allowing for a maximum deviation of 10% from the average. All crowns were sectioned perpendicular to the long axis, 17 mm from the apex, with a water-cooled diamond disk (No. 7020; KG Sorensen, Barueri, SP, Brazil) and the roots were stored in distilled water at 37 °C.

The root surfaces were covered with petroleum jelly and the roots were embedded in a self-polymerizing polystyrene resin (AM 190 Resin; AeroJet, São Paulo, SP, Brazil) up to the coronal margin. A radiographic film with a central circular hole was used to stabilize the teeth for the embedding procedure. This assembly was placed with the coronal limit faced down into a hole on a wooden board, leaving the root in a vertical position perpendicular to the supporting radiographic film. A plastic cylinder (25 mm in diameter and 37 mm long) was placed around the root and fixed in position with a cyanoacrylate adhesive (Super Bonder; Loctite, Itapevi, SP, Brazil) and red wax. The resin was prepared according to the manufacturer's instructions and inserted into the cylinder. The resin cylinder was axially sectioned (Fig. 1A) in a high-precision cutting machine (Isomet 1000; Buehler, Lake Bluff, IL, USA) to allow exposure of the mesial and distal root surfaces. Two strain gages were fixed on the distal root surface and two thermocouples on the mesial root surface, positioned symmetrically on the external root surface at two different regions: 2 mm from cervical region and 10 mm from the alveolar bone (Fig. 1A). A metallic device was developed for an effective fixation of the resin cylinder on the workbench. The device consisted of a rectangular aluminum base with a central slot for positioning the resin cylinder (controlled by a lateral screw) and a lateral polytetrafluoroethylene support on the mesial side with two slots (8 mm apart from each other) to sustain the cervical and apical thermocouples. Finally,

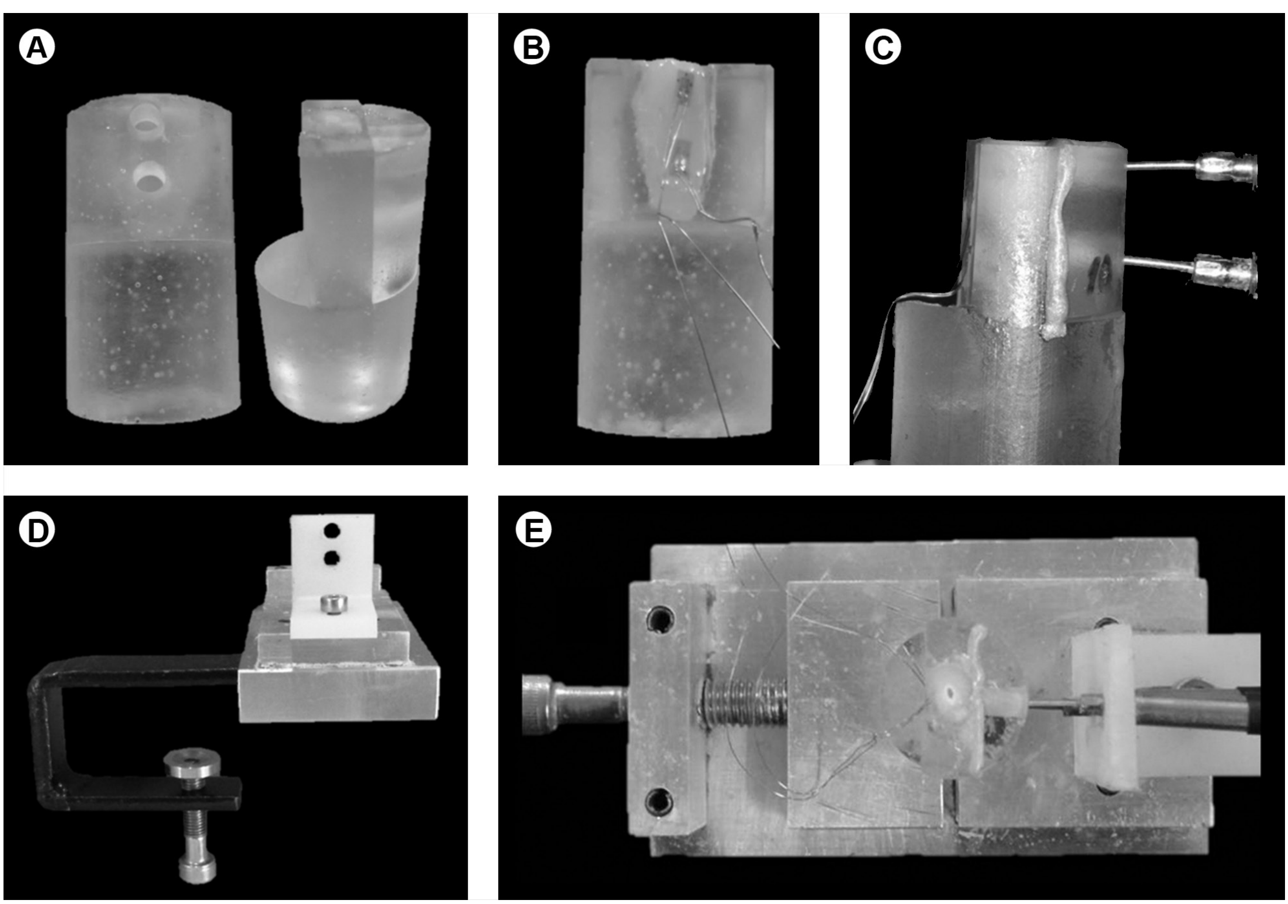

Figure 1. Experimental device used for temperature rise and strain measurement. A: Cylinder for strain gage and thermocouple attachment. B: Cylinder sustaining apparatus. C: Cervical and apical strain gages fixed in the distal root surface region. D: Lateral polytetrafluoroethylene support to fixe the cervical and apical J-thermocouples on mesial root surface region. E: Experimental device with sample connected to the strain gauges and thermocouples.

a wire loop connected to the aluminum base attached the set to the workbench by a screw in the lower portion of the loop surrounding the workbench (Fig 1B).

Temperature Rise Measurement

The J-type thermocouple (5TC-TT-J-40-36; Alutal Siebeck Sensors, São Paulo, SP, Brazil) was used for temperature rise measurement. The device is made of iron and constantan alloys (Cu 55% + Ni 45%) represented by two terminals: a positive pole with a white edge and a negative pole with a red end. Externally, the thermocouple is coated with black rubber and includes a stainless steel rod, an active circular tip (3.0 mm diameter) and a brass base, which was custom made for this study. The J-type thermocouple can capture temperature variations ranging from - 20 °C to + 800 °C with a ±0.2 °C accuracy. The lateral polytetrafluoroethylene support on the cylinder apparatus (Fig. 1D) stabilized the thermocouple and maintained it in direct contact with the external root surface. The thermocouples were connected to the data acquisition device (ADS0500IP; Lynx Technology, São Paulo, SP, Brazil). The data were transferred to a computer, using specific acquisition signal transformation by data analysis software (AqDados 7.02 and AqAnalisys; Lynx). During the endodontic and post rehabilitation procedures, a temperature value was recorded by each thermocouple at 0.25 s intervals.

Strain Measurements

For the strain measurement tests, two strain gages (PA-06-038AA-120LEN; Excel Sensors, São Paulo, Brazil) were fixed on all the samples, both aligned to the root long axis (Fig. 1C). A 2-mm-thick layer of silicon resin (Silicon Resin, Excel Sensors) coated the strain gages to protect them from contact with the irrigant. For the strain gage attachment, the root surface was etched with 37% phosphoric acid for 15 s, rinsed with an air water spray and air-dried. Sequentially, the strain gages were bonded with cyanoacrylate adhesive and connected to a data acquisition system adjusted at ½ Wheatstone bridge channel (ADS0500IP; Lynx). A passive specimen with two strain gages attached but not subjected to endodontic procedures and post cementation was mounted as compensation for temperature fluctuations. The obtained data were transferred to a computer using specific acquisition, signal transformation and data analysis software (AqDados 7.02 and AqAnalisys; Lynx). During the endodontic and post rehabilitation procedures, a temperature value was recorded by each thermocouple at 0.25 s intervals.

Root Canal Preparation and Irrigation

A single operator calibrated to use the rotary Ni-Ti instrumentation and the Pro Taper™ Universal Rotary System (Dentsply Maillefer, Ballaigues, Switzerland) performed all endodontic and restorative procedures. The root canals were instrumented at a working length (WL) of 16 mm (1 mm from the apex) with file driven by an electric engine at 350 rpm with 2.6 N/cm torque (X-Smart; Dentsply Maillefer) in the sequence recommended by the manufacturer for the crown-down technique: (1) the Protaper SX file (one half of the WL), S1 and S2 files (the full WL), in which all three files prepared the cervical and middle portion of the canals; (2) the F1, F2 and F3 files (the full WL) prepared the apical portion; and (3) the F4 and F5 files were used to enlarge the apical third of the root canal (the zone with the smallest root diameter). One rotary kit was used to prepare 7 specimens and then replaced. Instrumentation was carried out with concomitant irrigation with 2 mL 0.12% chlorhexidine gluconate, followed by a final flush with 10 mL of the same solution. The irrigation needle was placed as deeply as possible into the root canal.

Root Canal Filling and Canal Relief

Using the lateral condensation technique, the root canal was filled with a gutta-percha master cone F5 ProTaper Universal (Dentsply), conventional gutta-percha accessory cones and a calcium hydroxide-based endodontic sealer (Sealer 26; Dentsply). Canal relief was performed immediately after filling, using a heated instrument (GP heater; Dentsply Maillefer) to remove the gutta-percha to a depth of 10 mm.

The specimens were randomly assigned to 3 groups (n=7), according to the type of post system: CPC: cast Ni-Cr alloy post and core (Ni-Cr alloy; Goldent, São Paulo, SP, Brazil); FGP: smooth conical fiberglass post (Exacto No. 2; Angelus, Londrina, PR, Brazil); and PSP: prefabricated threaded steel post (Europost No. 5317; Anthogyr, Sallanches, France).

Post Space Preparation

For CPC and FGP, root canal walls were enlarged to a depth of 10 mm with a # 2 calibrated bur, corresponding to the fiberglass conical post (coronal diameter 1.6 mm and apical diameter 1.0 mm; Angelus). For PSP, one #4 Peeso bur was used, and the canal walls were enlarged to the root canal post space. During post space preparation, constant irrigation was performed with 10 mL distilled water.

Post Modeling

Prefabricated polycarbonate patterns (Pinjet; Angelus) were used for CPC. The patterns were relined using a polymerizing acrylic resin in the root canal (Duralay; Reliance Dental, Worth, IL, USA) until passive retention was achieved. The patterns were investment casts in nickel-chrome (Ni-Cr) alloy (Kromalit; Knebel, Porto Alegre, RS, Brazil).

Post Trying

In preparation for complete insertion into the post-space preparation, the posts were tried in each specific root canal prior to cementation. For PSP, the root canal was threaded 10 mm.

Table 1. Mean temperature rise (in ºC and ± SD) and statistical categories defined by Tukey's test (n=21) as a function of root location during the endodontic therapy procedures

Endodontic therapy procedures	Cervical	Apical
	Mean (SD)	Mean (SD)
Root canal preparation	1.3 (0.5) Aa	1.4 (0.5) Aa
Final rinse and drying	0.2 (0.1) Aa	0.3 (0.1) Aa
Obturation process	1.2 (0.5) Aa	1.0 (0.4) Aa
Canal relief	5.5 (1.5) Bb	3.6 (0.9) Ba

Different letters indicate statistically significant difference (p<0.05). Capital letters were used to compare the values in columns (endodontic therapy procedure); lowercase letters were used to compare the values in rows (root region).

Post Cementation (Self-curing Phase and Light-curing Phase)

All posts were cemented with self-adhesive resin cement (RelyX U100; 3M-ESPE). Before cementation, CPC and PSP were sandblasted with 50 µm aluminum oxide particles with 2 bar pressure for 10 s (Microblaster; Bio-Art, Sao Carlos, SP, Brazil) and cleaned in distilled water under ultrasonic vibration. FGP was etched with 24% hydrogen peroxide for 1 min (17) and, after drying, a silane agent was applied for 1 min (Silano; Angelus). The self-adhesive resin cement (RelyX U100; 3M-ESPE) was prepared according to the manufacturer's instructions, introduced into the canal with a K-file and the post was seated under digital pressure for 5 min. After 5 min, the resin cement was light-cured at each coronal root surface (buccal, lingual and occlusal) for 40 s using a halogen curing lamp (Optilux 501; Kerr Corporation, Orange, CA, USA) with 1000 mW/cm² light intensity. Data recording was completed 2 min after cementation.

Table 2. Mean and standard deviation of temperature rise in ºC and statistical categories defined by Tukey's test (n=7) as function of root location and post type during the post rehabilitation

Post rehabilitation procedures	Post type	Cervical		Apical	
		Mean (SD)	Range	Mean (SD)	Range
Post space preparation	FGP	7.9 (3.6) Aa*	4.1–14.7	8.2 (3.6) Aa*	4.2–13.2
	CPC	8.1 (1.4) Aa*	6.2–10.8	7.7 (1.1) Aa*	5.9–9.3
	PSP	7.2 (1.6) Aa*	5.4–9.2	7.0 (2.3) Aa*	4.0–10.6
Post modeling	CPC	1.8 (0.5)	1.2–2.3	1.6 (0.3)	1.2–2.3
Post trying	FGP	0.2 (0.2) Aa	0.0–0.4	0.2 (0.1) Aa	0.0–0.3
	CPC	0.2 (0.1) Aa	0.1–0.4	0.2 (0.1) Aa	0.0–0.4
	PSP	0.3 (0.2) Aa	0.1–0.6	0.3 (0.1) Aa	0.1–0.4
Resin cement self-curing phase	FGP	0.3 (0.1) Aa	0.0–0.5	0.3 (0.2) Aa	0.0–0.3
	CPC	0.4 (0.2) Aa	0.1–0.9	0.4 (0.3) Aa	0.1–0.9
	PSP	0.5 (0.3) Aa	0.1–0.9	0.4 (0.2) Aa	0.1–0.7
Resin cement light-curing phase	FGP	3.5 (0.9) Ab	2.0–5.0	0.9 (0.2) Aa	0.6–1.3
	CPC	2.6 (1.5) Ab	0.5–4.8	1.2 (0.1) Aa	1.1–1.4
	PSP	2.9 (1.3) Ab	2.1–5.5	1.4 (0.5) Aa	0.7–1.9

Different letters indicate statistically significant difference (p<0.05). Capital letters were used to compare the groups in columns (post factor) within each endodontic therapy procedure; lowercase letters were used to compare the groups in rows (root region).
*Indicates statistically significant difference among post rehabilitation procedures within each post system (p<0.05).

Statistical Analysis

Firstly, the data were submitted a Shapiro-Wilk demonstrating that data presented normal distribution. To compare the temperature rise and strain generated during each endodontic procedure, data were analyzed by two-way ANOVA (4x2: four endodontic phases and two root regions) and Tukey's test (α=0.05). Next, to compare the temperature rise and strain generated in each post rehabilitation procedure, data were analyzed by two-way ANOVA (3x2: three post systems and two root regions) and Tukey's test (α=0.05). Additionally, for CPC, the temperature rise and strain generated during all post rehabilitation procedures were analyzed by one-way ANOVA and Tukey's test (α=0.05).

Results

Temperature Rise Values

The mean temperature rise in °C (mean and standard deviation) for the evaluated procedures involving endodontic therapy procedures and post system steps are presented in Table 1 and Table 2, respectively. The temperature rise was significantly higher during the canal relief procedure than during all other endodontic procedures (p<0.001). During the canal relief the temperature rise was significantly higher in the cervical region than in the apical region (p<0.001).

Post space preparation caused significantly higher temperature increases than other therapy procedures for all tested posts. In the apical root region, the irrigation, post trying and post cementation resulted in significantly lower temperature changes than other therapy procedures. The resin cement light-activation resulted in significantly higher temperature increase in the cervical region than in the apical area for all groups. CPC post modeling resulted in higher root strain level similar to the level of post preparation.

Strain Values

The root strain (mean and standard deviation) for the evaluated procedures involving endodontic therapy procedures are presented in Table 3. The canal relief resulted in significantly higher strain than other endodontic procedures, irrespective of the root region (p=0.009). The root canal preparation resulted in higher dentin strain on apical region than on cervical region (p<0.010). On the other hand, root canal filling resulted in higher dentin strain on the cervical region (p<0.004).

The root strain (mean and standard deviation) for the evaluated procedures involving post rehabilitation procedures are presented in Table 4. The strain values were significantly higher in the apical region than in the cervical region during post space preparation (p<0.009), irrespective of post type. At the end of the measurement, PSP produced significantly higher strain than FGP on both root dentin regions. Additionally, the post space preparation procedure resulted in significantly higher root dentin strain than all other procedures. The CPC post modeling resulted in high strain values similar to the post space preparation. The signals recorded by the data acquisition system to strain and temperature rise in all steps for all groups are shown in Figure 2.

Table 3. Mean maximum strain (in µS and ± SD), and statistical categories defined by Tukey's test (n=21) as function of root location and endodontic therapy procedure

Endodontic therapy procedures	Maximum µS (SD)	
	Cervical	Apical
Root canal preparation	71.7 (22.4) [Aa]	113.4 (29.4) [Ab]
Final rinse and drying	63.5 (19.2) [Aa]	64.3 (16.1) [Aa]
Obturation process	115.1 (48.8) [Ab]	78.8 (34.2) [Aa]
Canal relief	208.8 (92.6) [Ba]	223.6 (81.0) [Ba]

Different letters designate statistically significant difference (p<0.05). Capital letters were used to compare the values in columns (endodontic therapy procedure); lower-case letters were used to compare the values in rows (root region).

Discussion

The first tested hypothesis was accepted, as the temperature rise and dentin strain generated during endodontic treatment were different among the endodontic procedures and between cervical and apical root region. Additionally, the second hypothesis was also accepted, since different post systems influence the temperature rise and dentin strain.

Analysis of the thermomechanical effects of endodontic treatment and the post rehabilitation process on root dentin is complex when the required information must be recorded in real time. Non-destructive methods, such as the strain gage measurement and the external root surface temperature measurement using thermocouples, showed that it is possible to quantify the strain level and temperature rise generated during the complex process of rehabilitation of endodontically treated teeth roots. Thermocouples function based on the thermoelectric effect, which results in an electric current when two dissimilar metal wires are joined together and subjected to temperature change. Their inherent limitation is that each thermocouple can measure temperature only at the contact

Table 4. Mean maximum strain (in µS and ± SD), and statistical categories defined by Tukey's test (n=21) as function of root location and endodontic therapy procedure

Post rehabilitation procedures	Post type	Cervical	Apical
Post space preparation	FGP	276.7 (120.3) [Aa]	473.9 (267.5) [Ab]
	CPC	272.9 (124.3) [Aa]	438.1 (254.5) [Ab]
	PSP	182.0 (61.8) [Aa]	313.0 (154.8) [Ab]
Post modeling	CPC	371.8 (299.8) [a]	462.4 (298.7) [a]
Post trying	FGP	146.7 (48.3) [Ba]	201.0 (76.9) [Ba]
	CPC	47.5 (39.0) [Aa]	36.1 (16.0) [Aa]
	PSP	281.0 (166.8) [Ca]	330.0 (196.3) [Ca]
Resin cement self-curing phase	FGP	167.9 (80.2) [Ba]	245.4 (169.9) [Ba]
	CPC	106.1 (43.2) [Aa]	72.1 (33.3) [Aa]
	PSP	290.4 (88.0) [Ca]	269.0 (192.2) [Ca]
Resin cement light-curing phase	FGP	233.4 (105.4) [Ba]	225.9 (129.6) [Ba]
	CPC	130.2 (60.4) [Aa]	80.1 (21.4) [Aa]
	PSP	314.2 (257.3) [Ca]	325.4 (249.8) [Ca]

Different letters indicate statistically significant difference (p<0.05). Capital letters were used to compare the groups in columns (post factor) within each endodontic therapy procedure; lowercase letters were used to compare the groups in rows (root region).

point of the surface. The contact area is an important factor to consider when temperature is measured, as larger contact areas can detect temperature rise more accurately (18). The thermocouples used in this study, J Type (5TC-TT-J-40-36, Alutal Siebeck Sensors, SP, Brazil) with a 3 mm diameter tip and a sustainable extension, were specifically designed for this study to provide a larger contact surface between the root dentin and the thermocouple sensor, allowing contact throughout the experiment.

Canal relief and post space preparation are considered the most critical heat generating procedures in endodontics (12,18). The canal relief showed a significantly higher

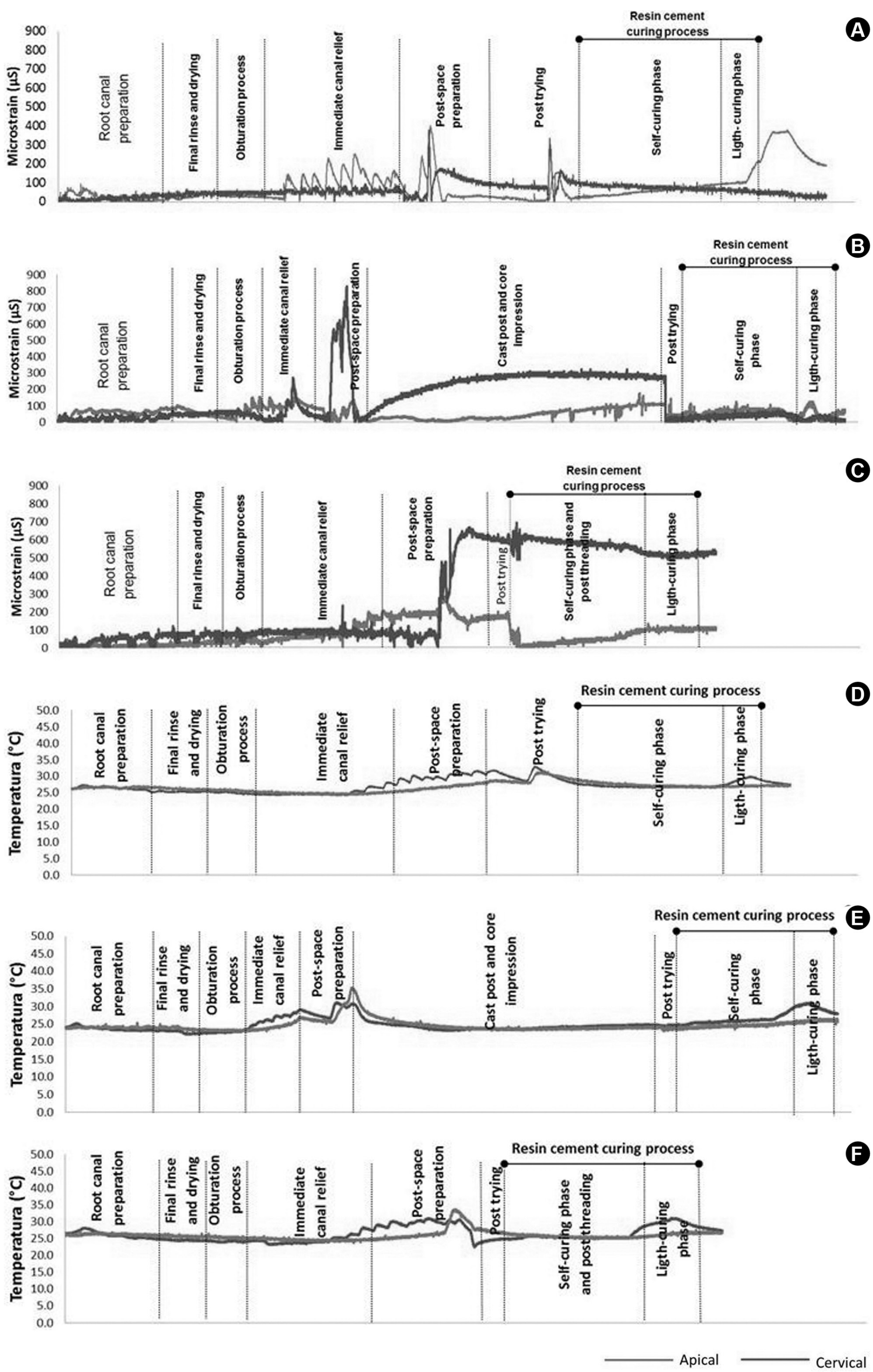

Figure 2. Typical curves for the experimental groups. A: Strain curve for FGP. B: Strain curve for CPC. C: Strain curve for PSP post. D: Temperature rise curve for FGP. E: Temperature rise curve for CPC. F: Temperature rise curve for PSP.

temperature rise on the cervical root surface region, but the range achieved in this procedure (3.0-7.8 °C) was lower than 10 °C, which is considered the critical temperature for tissue damage (8). Those values could be explained by using a larger heated instrument to remove gutta-percha from two-thirds of the root canal. This instrument may contact canal walls, which causes temperature rise. A temperature rise range of 10.8-14 °C was achieved during the post space preparation for FGP and CPC, while PSP produced a temperature rise of 9.2-10.6 °C. All groups exceeded the critical temperature for tissue damage. Some factors may influence the heat generation during post space preparation, such as the reamer type, the operator force, the friction between the reamer and canal walls and the use of new drills (8,12,16). However, although it is essential, irrigation did not sufficiently prevent the temperature rise levels reached during the post space preparation. This procedure was performed with continuous water cooling, which means that with intermittent irrigation, the temperature rise could be much higher than that found in this study. The clinicians must be careful during the post space preparation using new drills that could cut dentin with less friction and lower temperature rise (19). In order prevent temperature rise, the post canal preparation should be performed intermittently, in association with continuous irrigation.

During post trying and post cementation, no significant temperature rise was verified before the light curing activation. However, when the resin cement was activated by the light-curing unit, the temperature increased significantly. For all the experimental groups, the temperature measurement showed significantly higher heat values on the cervical root surface region. This result was due to the proximity of the light-curing sources to the cervical region rather than the apical region. The heat is transferred to external surface reaching the highest levels in the cervical region. The adequate curing of the resin cement is required to predict a good clinical performance for the post cemented into the root canal (20), and in this study, the temperature rise levels reached during the light curing of resin cement did not exceed the critical temperatures that could damage the periodontal ligament cells.

Strain gage measurement has been used to analyze the influence of endodontic treatment and different post types (3). For this study, particular attention was necessary to prevent damaging the strain gages during the experiment since in the pilot study, it was verified that the application of irrigant solution over the strain gage resulted in incorrect data recording. Therefore, a silicon resin was used to cover the strain gages, obtaining a 2 mm protection layer.

The ProTaper Universal Rotary system uses progressively tapered Ni-Ti rotary files in the same instrument (21) and the shaping instruments present greater flexibility than the finishing instruments (22), which demonstrate that our results were not overestimated by the file type. The strain values were significantly higher in the apical root region during the root canal preparation, possibly due to the ProTaper finishing files F4 and F5 used to enlarge the apical third of the root canal (the zone with the smallest root diameter).

Regarding canal filling, the use of substantial condensation force is necessary to achieve deep initial spreader insertion (23). This finding may explain the higher strain levels recorded in the cervical region than in the apical region. The use of a larger instrument and the movements performed by the operator during the gutta-percha condensation resulted in more contact (for a longer time) on the cervical root canal walls.

Obermayr et al (5) described canal filling and post cementation as procedures that result in high relative deformation, but that study measured the strain only at the cervical region. In the present study, the apical root surface region showed significantly higher strain values during the post space preparation procedure. The root canal has natural taper and it could automatically result in more friction between the bur and the dentin canal walls during the post space preparation, leading to stress concentration on the apical region. Additionally, the root dentin was less thick in the apical region than in the cervical region, explaining the values achieved in this region.

High heat levels were followed by greater amounts of strain. This occurs because the heat produces an initial dentin contraction, followed by expansion (24). The lowest strain levels were achieved during the root canal preparation, and final rinse and drying procedures, as the temperature rise was prevented with irrigating solution. The resin cement self-curing phase for CPC and FGP also showed low strain levels. The lower strain levels recorded in those procedures could be explained by the absence of thermal stimuli and the passive setting of the FGP and CPC. The insertion of the post did not result in additional friction with the root canal walls, which prevented strain generation. In contrast, PSP are actively inserted into the root canal. During the threading of PSP the screws penetrated into the dentin walls, generating the residual strain. During the resin cement light-curing phase were found higher values of strain. This finding could be explained by the accumulation of residual stress on the tooth structure due to the residual shrinkage stress produced by light-activation of the resin cement (24). Another explanation for the strain increase is the temperature generated by the light curing unit (25). For CPC, the residual strain accumulation was lower than that for the other groups, as the post cementation was performed after a long period of time. The laboratory phase is needed to cast the post and the core, factors that could not be controlled. The data recording was also interrupted because this type of post requires more than one session to complete the intracanal rehabilitation.

Additional studies should be performed to assess factors at the macro- and microscopic levels, studying the characteristics of root dentin, periodontal ligament and alveolar bone cells to minimize the factors that may lead to immediate or mediate restorative procedure failures. Most evaluated procedures produced similar low temperature rise and strain values on the cervical and apical root surface regions, except for the canal relief and post space preparation. Post-space preparation is a critical procedure and caution must be taken to minimize damage to the surrounding tissues, as the continuous application of water coolant. This study also showed that prefabricated steel posts, inserted actively, resulted in high strain during post trying and cementation, which is another important and confirmatory information that supports the non-indication of this post type for rehabilitation of the endodontically treated teeth.

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Resumo

Este estudo investigou os efeitos de diferentes etapas do tratamento endodôntico e da inserção de diferentes tipos de retentores na deformação e aumento de temperatura na dentina radicular apical e cervical. Vinte e um dentes caninos humanos extraídos tiveram dois extensômetros colados à superfície da raiz distal e dois termopares ligados à superfície da raiz mesial (cervical e apical). A deformação e aumento de temperatura foram registrados durante os seguintes procedimentos: preparo do canal radicular, irrigação final e secagem, obturação do canal, alívio do canal; em seguida, os dentes foram divididos em três grupos (CPC, núcleo moldado e fundido; FGP , pino de fibra de vidro, e PSP pino pré-fabricado em aço-inoxidável, n=7). Os dados foram continuamente mensurados durante a modelagem do núcleo (somente para o CPC), inserção e cimentação dos retentores. Os dados foram submetidos a análise de variância fatorial, seguido pelo teste de Tukey (α=0,05). O preparo do canal para o retentor causou o maior aumento de temperatura (4,0-14,9 °C) e maior deformação na região apical independente do tipo de retentor. A ativação com luz resultou em significativo aumento de temperatura na região cervical, para todos os grupos. O alívio do canal e o preparo para o pino produziram maiores aumentos de temperatura. A modelagem do CPC resultou em maior nível de deformação da raiz em nível similar ao preparo para o retentor. O PSP resultou em maior deformação durante a inserção e ao final da cimentação.

References

1. Soares CJ, Valdivia AD, da Silva GR, Santana FR, Menezes M de S. Longitudinal clinical evaluation of post systems: a literature review. Braz Dent J 2012;23:135-140.
2. Menezes MS, Queiroz EC, Campos RE, Martins LRM, Soares CJ. Influence of endodontic sealer on fibreglass post bond strength to root dentin. Int Endod J 2008;41:476-484.
3. Silva GR, Santos-Filho PC, Simamoto-Júnior PC, Martins LR, Mota AS, Soares CJ. Effect of post type and restorative techniques on the strain and fracture resistance of flared incisor roots. Braz Dent J 2011;22:230-237.
4. Soares CJ, Santana FR, Silva NR, Pereira JC, Pereira CA. Influence of the endodontic treatment on mechanical properties of root dentin. J Endod 2007;33:603-606.
5. Obermayr G, Walton RE, Leary JM, Krell KV. Vertical root fracture and relative deformation during obturation and post cementation. J Prosthet Dent 1991;66:181-187.
6. Ratih DN, Palamara JEA, Messer HH. Temperature change, dentinal fluid flow and cuspal displacement during resin composite restoration. J Oral Rehabil 2007;34:693-701.
7. Atrizadeh F, Kennedy J, Zander H. Ankylosis of teeth following thermal injury. J Period Res 1971;6:159-167.
8. Eriksson AR, Albrektsson T. Temperature threshold levels for heat-induced bone injury: a vital microscopic study in the rabbit. J Prosthet Dent 1983;50:101-107.
9. Matthews LS, Hirsch C. Temperature measured in human cortical bone when drilling. J Bone Join Res 1972;54:297-308.
10. Eriksson A, Albrektsson T, Grane B, McQueen D. Thermal injury to bone: a vita-microscopic description of heat effects. Int J Oral Surg 1982;11:115-121.
11. Sauk JJ, Norris K, Foster R, Moehring J, Somerman MJ. Expression of heat stress protein by human periodontal ligament cells. Journal of Oral Pathology 1988;17:496-499.
12. Saunders EM, Saunders WP. The heat generated on the external root surface during post space preparation. Int Endod J 1989;22:169-173.
13. Hulsman M, Peters OA, Dummer PMH. Mechanical preparation of roots canals: shaping goals, techniques and means. Endod Top 2005;10:30-76.
14. Mousavi SA, Kargar-Dehnavi V, Mousavi SA. A novel approach to determine the effect of irrigation on temperature and failure of Ni-Ti endodontic rotary files. Dent Res J 2012;9:281-287.
15. Hardie EM. Further studies on heat generation during obturation techniques involving thermally softened gutta-percha. Int Endod J 1987;20:122-127.
16. Tjan AHL, Abatte MF. Temperature rise at root surface during post space preparation. J Prosthet Dent 1993;69:41-45.
17. de Sousa Menezes M, Queiroz EC, Soares PV, Faria-e-Silva AL, Soares CJ, Martins LR. Fiber post etching with hydrogen peroxide: effect of concentration and application time. J Endod 2011;37:398-402.
18. Mc Cullagh JJP, Setchell DJ, Gulabivala K, Hussey DL, Biogioni P, Lamey PJ, et al.. A comparison of thermocouple and infrared thermographic analysis of temperature rise on the root surface during continuous wave condensation technique. Int Endod J 2000;3:326-332.
19. Ulusoy N, Denli N, Atakul F, Nayyar A. Thermal response to multiple use of a twist drill. J Prosthet Dent 1992;67:450-453.
20. Soares CJ, Pereira JC, Valdivia AD, Novais VR, Meneses MS. Influence of resin cement and post configuration on bond strength to root dentine. Int Endod J 2012;45:136-145.
21. Machado MEL, Sapia LAB, Cai S, Martins GHR, Nabeshima CK. Comparison of two rotary systems in root canal preparation regarding disinfection. J Endod 2010;36:1238-1240.
22. Grazziotin-Soares R, Barato Filho F, Vanni JR, Almeida S, Oliveira EP, Barletta FB, et al.. Flexibility of K3 and ProTaper universal instruments. Braz Dent J. 2011;22:218-222.
23. Schmidt KJ, Walker TL, Johnson JD. Comparison of nickel-titanium and stainless-steel spreader penetration accessory cone fit in curved canals. J Endod 2000;26:42-44.
24. Linsuwanont P, Palamara JE, Messer HH. Thermal transfer in extracted incisors during thermal pulp sensitivity testing. Int Endod J 2007;41:204-210.
25. Jongsma LA, Jager Ir N, Kleverlaan CJ, Feilzer AJ. Reduced contraction stress formation obtained by a two-step cementation procedure for fiber posts. Dental Materials 2011;27:670-676.

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