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Infrared Thermographic Comparison of Temperature Increases on the Root Surface during Dowel Space Preparations Using Circular versus Oval Fiber Dowel Systems

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Keywords
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Abstract

Purpose: The purpose was to evaluate temperature increases during dowel space preparations with oval and circular fiber dowel systems.
Materials and Methods: This study included 42 single-rooted human mandibular premolars. Roots were scanned with cone-beam computerized tomography (CBCT) to determine the ovoid root canal morphology. Root canals were treated with Ni-Ti rotary instruments and obturated. A second CBCT was taken to determine the thinnest dentin thickness of each root. Roots were randomly divided into two groups ($n = 21$) according to the fiber dowel system used: group 1, circular fiber dowel system (D.T. Light-Post); group 2, oval fiber dowel system (Ellipson Post). Dowel spaces were prepared using a circular fiber dowel drill and a diamond-coated ultrasonic tip with an oval section under water cooling until 9 mm dowel spaces were obtained. Temperature changes were recorded from the thinnest root surfaces using a FLIR E60 thermal imaging camera.
Results: Temperature increases were significantly greater with the circular fiber dowel system than with the oval fiber dowel system ($p < 0.05$).
Conclusions: Although both dowel systems generated high temperature increases on root surfaces, the relatively lower temperature increase associated with the use of oval fiber dowels in ovoid canals makes it preferable to the use of circular fiber dowels.

Root canal treatments consist of chemomechanical preparation and obturation, followed by adequate restoration.[1] Because root canal-treated teeth often have extensive loss of tooth structure due to carious lesions, previous restorations, or fractures, they commonly require complex restorations, such as dowel and core restorations, to promote retention of the final restoration.[2-4]

Dowel space preparation involves partial removal of the root canal filling, and enlargement and shaping of the root canal space is sometimes necessary.[5] One consequence of dowel space preparation is a rise in temperature on the outer root surface.[6,7] Several studies have investigated the temperature at which damage to the periodontal ligament and bone is initiated; reported critical temperatures range from 43°C to 56°C.[5,8-12]

To avoid the need to use circular fiber dowels in oval canals, oval fiber dowels have been introduced recently with the aim of achieving better adaptation to the dowel space walls. Oval fiber dowels reduce the resin cement thickness and improve dowel retention strength, as they anatomically reproduce the oval form of root canals.[13]

To date, temperature increases during dowel space preparation procedures have not been compared between oval and circular fiber dowel systems. The null hypothesis of this in vitro study was that the temperature changes at the external surface of teeth during dowel space preparation in ovoid root canals would not differ significantly between the use of oval fiber dowel ultrasonic tips or circular fiber dowel drills.

Materials and methods

Similarly sized human mandibular first premolars extracted for periodontal reasons were collected and stored in normal saline. Teeth with fully developed apices and a single canal were included in this study, whereas teeth with caries, prior root canal therapy, or fractures/cracks were excluded. All teeth were

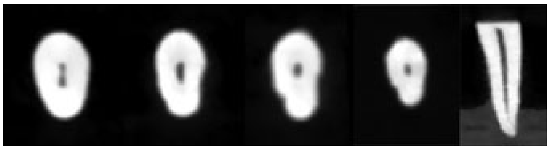

Figure 1 CBCT images of a root from the top of the coronal root section, 3-6-9 mm below the top of the coronal root section and entire root surface, respectively, before root canal preparation to determine the ovoid root canal morphology.

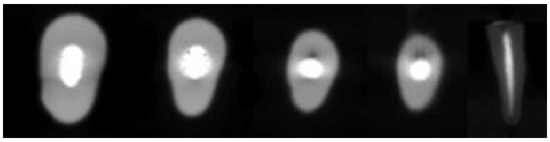

Figure 2 CBCT images of a root from the top of the coronal root section, 3-6-9 mm below the top of the coronal root section and entire root surface, respectively, after the root canal obturation to determine the remaining dentin thickness of each root.

scanned using cone-beam computerized tomography (CBCT) (NewTom 5G FP, Verona, Italy) system before root canal preparation to determine the ovoid root canal morphology (Fig 1). Teeth were identified as oval when the ratio of the long to short canal diameter, measured at 5 mm from the apex, was ≥2, as described by Wu et al.[14] A total of 42 teeth with ovoid canals were selected for the study. The root surfaces were debrided with an ultrasonic scaler (Cavitron; Dentsply, York, PA) and gently planed by hand with curettes to remove adherent soft tissues. The teeth were cut perpendicular to the long axis at the cementoenamel junction with a slow-speed diamond saw (Isomet; Buehler, Lake Bluff, IL). To standardize the root canal length, the roots were cut to a uniform length of 14 mm. The working length was established 1 mm short of the anatomic apex. ProTaper rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) were used on all roots, and ProTaper F3 was the master apical file. Five milliliters of 2.5% NaOCl was used for irrigation between instruments. The final rinse was performed for 1 minute using 5 mL 17% ethylenediaminetetraacetic acid (EDTA), followed by copious irrigation with distilled water. Each canal was dried with paper points and obturated with cold lateral condensation using gutta-percha (Dentsply Maillefer, Petropolis, Brazil) and resin sealer (AH Plus; Dentsply DeTrey GmbH, Konstanz, Germany). Access cavities were filled with temporary filling material (CavitTM-G; 3M ESPE AG, Seefeld, Germany), and the teeth were stored at 37°C and 100% humidity for 7 days to allow the sealers to set.

A second CBCT was taken (Fig 2) after the root canal obturation to determine the remaining dentin thickness of each root to measure thermal changes on the thinnest part of the root dentin during dowel space preparations. Each root was embedded in $2 \times 2 \times 0.2$ cm^3 acrylic plates with a pattern resin (Pattern Resin LS^{TM}, GC USA, Alsip, IL) to prevent the root surfaces from being exposed to the water spray during thermal imaging.

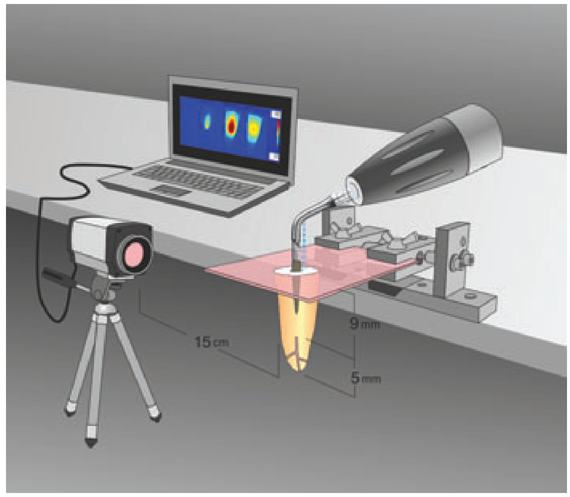

Figure 3 Experimental setup established for thermal measurements.

Thermal measurement

The temperature measurement method described by Lipski et al[5] was applied. To obtain dowel space preparations and temperature measurements, the specimens were fixed with the entire root surfaces exposed to air using a vice produced for this study. Temperature changes were recorded on the thinnest root surface using a FLIR E60 thermal imaging camera (Extech Instruments Corporation, Waltham, MA) and its dedicated software package. The camera was mounted 15 cm from the specimen on a stand perpendicular to the root surface to record all thermal measurements from the same distance (Fig 3). The thermogram recordings were initiated 2 seconds prior to creating the dowel space, and continued at 2-second intervals for a total time of 90 seconds (Figs 4 and 5). The experiment was carried out under controlled environmental conditions (ambient temperature 26 ± 0.9°C; relative humidity, 44 ± 5%; air flow, <0.5 m/s). The camera was calibrated for distance, ambient temperature, and emissivity of the root tissue.[5,15] Distance was measured at 15 cm using a ruler for an optimum focusing of the camera on the specimens, and the temperature of the camera was checked before each measurement to ensure it was the same as the ambient temperature. Emissivity is defined as the ratio of the radiant power emitted by the object to that of a blackbody at an equal temperature. (A "blackbody" is an object that absorbs all radiation.) In this study the emissivity of the root tissues was accepted to be 0.91, as previously measured by Lipski et al.[5]

Roots were randomly divided into two groups of 21 roots each, and the following procedures were performed. Group 1: The gutta-percha was removed using a #3 Gates Glidden bur (Mani Inc., Tochigi, Japan) until a 9-mm dowel space was obtained. First, a preparation drill (D.T. #0.5; Bisco Inc., Schaumburg, IL) was used under continuous water cooling from a handpiece (25 mL/min). After a 30-second pause to change the drill, the root canals were enlarged using a finishing drill (D.T. #2; Bisco Inc.) under continuous water cooling from a handpiece (25 mL/min). A 2.5% NaOCl solution was used to lubricate the root canal before and after the first drill

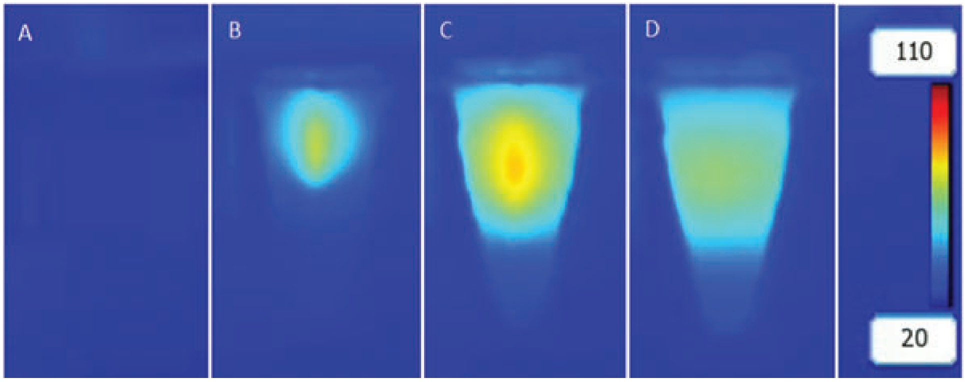

Figure 4 Dowel space preparation performed with oval ultrasonic instrument; (A) directly before dowel space preparation, (B) during dowel space preparation, (C) directly after dowel space preparation, (D) 5 seconds after dowel space preparation.

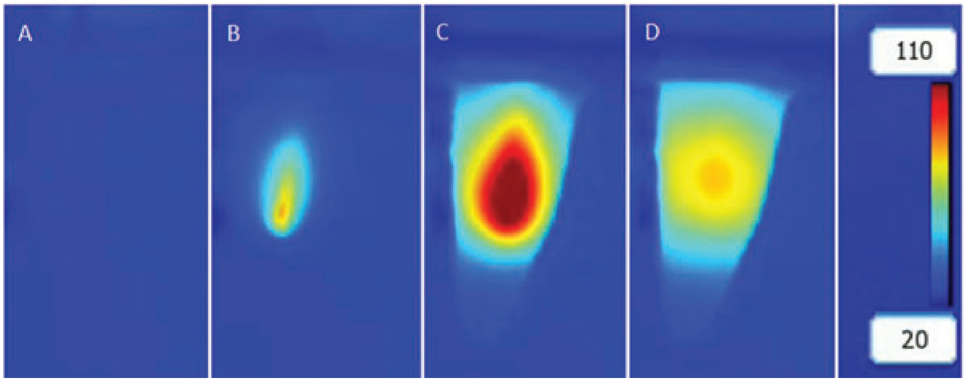

Figure 5 Dowel space preparation performed with circular rotary instrument: (A) directly before dowel space preparation, (B) during dowel space preparation, (C) directly after dowel space preparation, (D) 5 seconds after dowel space preparation.

preparation. The drill speed was set at 8000 rpm, and the depth of the dowel space preparation was 9 mm. Group 2: The gutta-percha was removed using a #3 Gates Glidden bur (Mani Inc.) until a 9-mm dowel space was obtained. A medium-grit (76-μm) diamond-coated ultrasonic tip with an oval section (Ellipson tip; RTD/Satelec, Merigcac, France) was mounted on an ultrasonic unit (Satelec P5 Newtron XS; Acteon Group, Mount Laurel, NJ) and used at medium power. During the preparations, continuous water cooling from a handpiece (25 mL/min) was used according to the manufacturer's directions.

During dowel space preparations, drills and ultrasonic tips were used gently until a glide movement was achieved at working length in all processes. In both groups, the highest temperature values during the dowel space preparation of each specimen were recorded, and temperature rises were determined by subtracting the ambient temperature from the highest temperature values.

Statistical analysis

All data sets were subjected to normality tests using the Shapiro-Wilk method, and the data were normally distributed. The independent samples *t*-test was used to compare the groups. Statistical analyses were conducted using SigmaPlot 12.0 software (Systat Software, San Jose, CA), and the level of significance was set at $p < 0.05$.

Results

Two specimens from group 1 were excluded from the statistical analysis because of a vertical root fracture in one specimen and a separated Gates Glidden bur in the other. Additionally, two specimens from group 2 were excluded from the statistical analysis because of a root perforation in one specimen and data recording problems from the infrared thermography camera for the other specimen. The analytical sample thus contained 19 teeth from each group.

Temperature increases and standard deviations and ranges of temperatures were recorded for each specimen in both groups (Table 1). Statistical analysis showed a difference in mean temperature increase between groups 1 and 2 ($p < 0.05$). The mean temperature increases for the circular fiber dowels (group 1) and oval fiber dowels (group 2) during dowel space preparations were 63.53 ± 26.01°C (32.7 to 126°C) and 47.63 ± 9.49°C (27 to 61.5°C), respectively.

Table 1 Mean temperature rises (°C), standard deviations, and ranges of temperatures recorded on the thinnest root surfaces for the oval and circular fiber dowel space preparations

Groups	Mean	Std. deviation	Min-Max	p
Ultrasonic tip with oval section (Ellipson tip)	47.637	9.496	27.0-61.5	**0.017**
Circular fiber dowel finishing drill (D.T #2)	63.530	26.010	32.7-126.0	

Discussion

With the exception of the maxillary central incisor and the palatal root of the maxillary first molar in the mesiodistal view, the cross-sectional anatomical shape of the coronal and/or middle third of a root canal is ovoid.[16,17] The endodontic restorative goal in fiber dowel applications should be to mimic the existing root canal shape; however, circular fiber dowel drills have round sections that weaken the proximal walls in this type of root canal. In ovoid roots, a circular fiber dowel preparation can significantly reduce the amount of remaining lateral dentin, thereby increasing the resin cement thickness and the likelihood of microleakage, and reducing retention and the probability for success.[18,19] In this study, mandibular single-rooted premolars were chosen, and ovoid root canal morphology was confirmed with CBCT.

As reported in the literature, oval fiber dowels may have some advantages compared with circular fiber dowels, such as a reduced resin cement thickness,[20] better open dentin tubule scores, and increased adhesion.[21] Instead of using a rotary instrument to prepare the dowel channel, a minimally invasive diamond-coated ultrasonic tip is used to precisely prepare the dowel space for the Ellipson fiber post.[13] Although studies have demonstrated that oval fiber dowels are more successful in oval root canals,[13,16] no study has compared temperature changes during dowel space preparation between oval and circular fiber dowel systems.

Thermocouple analysis, infrared thermography, and finite element analysis (FEA) have been used to determine heat transition through dentin.[5,22-25] FEA yields a unique result for each tooth model, but the analysis of all models would be time-consuming and expensive and would require additional computer engineering.[22] Hussey et al[23] first used infrared thermography in dental research. In their study, the thermal image recording system was also used to measure the entire root surface for subsequent data analysis, rather than using thermocouple analysis, which provides only point data.[23]

Several studies have reported that a reduction in dentin thickness may increase the heat transfer to the periodontium.[26,27] One study evaluating intraradicular heat transfer to the periodontium using ultrasonic devices showed that a preoperative radiographic determination of dentin thickness may be useful for measuring heat on the outer root surface.[27] In light of these studies, our study used CBCT to determine dentin thickness prior to dowel space preparation to measure thermal changes on the thinnest part of the root dentin.

In the present study, temperature increases were significantly higher with circular fiber dowel drills than with oval ultrasonic tips. This result does not support the null hypothesis that temperature increase would not differ between the oval fiber dowel ultrasonic tips and the circular fiber dowel drills during dowel space preparation in ovoid root canals.

Lipski et al[5] measured the temperature increase on the mesial root surfaces of premolars during dowel space preparation with and without water cooling using a thermal imaging camera. Root surface temperature increases were significantly lower when dowel spaces were created with water cooling (6.86 ± 1.18°C), compared with dry dowel preparation (53.75 ± 8.19°C). Although water cooling was provided for both groups in this study, the temperature increased 47°C when using the oval ultrasonic instruments and 63°C when using circular dowel drills. This difference may be due to our strict selection of oval root canals, which may result in the creation of more frictional force at the proximal walls, especially with circular fiber dowel drills, and to the collection of measurements from the thinnest root dentin surfaces, as determined by CBCT.

Hussey et al[23] measured the temperature at the root surface during dowel space preparation without water cooling. The authors used Red ParaPost drills and found a mean increased temperature of 81.1°C using a thermal imaging camera. The Red ParaPost drill has a tip diameter of 1.25 mm, which is larger than those of the circular fiber dowel drill and oval ultrasonic tip used in our study (1.0 mm and 1.1 mm, respectively). The relatively high scores reported by Hussey et al[23] may be due to the generation of more heat energy by the friction created by the use of large-diameter drills without water cooling.

Although both dowel systems examined here generated high temperature increases on root surfaces in oval canals, this increase was lower with the oval fiber dowel system than with the circular fiber dowel system. We suggest that the ultrasonic tips of the oval dowel system should be used intermittently under effective water cooling.

The limitation of the current study is that this study was carried out in vitro with the absence of the surrounding periodontium, oral environment, and body temperature. As a result, this study did not represent real clinical situations, such as the effect of systemic circulation on heat transfer to the periodontal tissues, and can be considered as the maximum temperature increase that may occur during dowel space preparation. Additionally, only the highest temperatures were recorded while preparing the dowel spaces, whereas the critical temperature level for periodontium damage or the return to a normal temperature was not evaluated. Therefore, further studies are needed to better reflect the clinical conditions encountered in patients undergoing dowel space preparation with oval and circular fiber dowel systems.

Conclusions

Temperature increases were compared in oval and circular dowel systems. While temperature increases were observed in both systems, they were significantly lower with oval fiber dowel ultrasonic tips than with circular fiber dowel drills. Therefore, oval fiber dowels may be preferred when placing a dowel, especially in ovoid root canals.

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