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Research Article

EFFECTS OF COLD LATERAL VERSUS WARM VERTICAL COMPACTION OBTURATION ON THE PUSH-OUT BOND STRENGTH OF BIOROOT™, A CALCIUM SILICATE-BASED SEALER

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ABSTRACT

Objective: BioRoot™ , which contains pure calcium silicate, is used in cold lateral compaction. However, hydroxyl ions are still released when BioRoot™ is used in warm vertical compaction. This study compared the effects of cold and warm vertical compaction obturation on the push-out bond strength of BioRoot™.

Methods: Specimens from 16 root canals instrumented with ProTaper Next X5 50/06 were divided into two groups (n=16 specimens per group). Group 1 was obturated using cold lateral compaction, whereas Group 2 was obturated using warm vertical compaction. All samples were incubated for 48 h (37°C, 100% humidity) and embedded into an acrylic block. Starting at 7 mm from the apex, two 2-mm-thick slices of each sample were cut. Dislodgement resistance was measured using a universal testing machine, and the push-out bond strength was calculated.

Results: There was a significant difference in the push-out bond strength value between cold (4.5–41.1 MPa) and warm (4.12–24.25 MPa) compaction obturation ($p<0.05$).

Conclusion: Cold lateral compaction provides better adhesion capability than warm vertical compaction in root canal obturation.

Keywords: Push-out bond, Calcium silicate-based, Cold compaction, Warm compaction.

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INTRODUCTION

Root canal treatment eliminates microorganisms and prevents recurrent tooth infection [1]. Several factors, such as root canal preparation, obturation, and final restoration, determine the success of treatment [1], and the quality of root canal obturation also important to determine tooth prognosis [2].

Root canal sealers are classified into zinc oxide eugenol, calcium hydroxide, glass ionomer, resin, silicon, and calcium silicate-based sealers [3,4]. Of these, calcium silicate-based develop rapidly because of their biocompatibility and bioactivity [5]. These sealers release bioactive material that can stimulate the formation of a tag-like structure between sealer and dentine [6-8]. Root canal obturation using gutta-percha and a calcium silicate-based sealer forms a secondary monoblock adhesion that strengthens the root structure [9].

BioRoot™ is the latest calcium silicate-based sealer that processed using active Biosilicate Technology [10]. Adhesion between cement and dentin in BioRoot™ is superior compared with other calcium silicate-based sealers [10]. The development of calcium silicate-based sealers involves the use of a single-cone technique [11]. This technique is easy to use and lower the risk of root fracture and periodontal structure trauma [2].

Warm vertical compaction produces a hermetic seal and stronger adhesion to dentine compared with the single-cone technique [12]. Camilleri reported that heat produced in warm vertical compaction affects the physical and mechanical properties of BioRoot™ but not its chemical properties [13].

Gade *et al.* compared the effects of cold lateral and warm vertical compaction on the push-out bond strength of Endosequence BC™ [14]. Statistically, they found no significant difference between the push-out bond strength after cold lateral and warm vertical compaction. The mode of failure in both techniques was a cohesive failure, indicating no significant difference between the effects of either technique on the push-out bond strength [14].

This study compared the effects of cold and warm vertical compaction on the push-out bond strength of BioRoot™.

METHODS

Specimens

In this study, we used 16 recently extracted human single-rooted mandibular premolars. The teeth were thoroughly cleaned and stored in saline solution at room temperature. Their crowns were cut transversally using a double-faced diamond disc to obtain a 16 mm standardized root length, and working lengths were established by inserting a #10 K-file (Dentsply, Tulsa, OK, USA) into the root canal terminus until it became visible through the apical foramen and then retracting it by 1 mm. Root canals with an initial apical #15 K-file were selected to standardize the root canal diameter.

ProTaper Next X5 50/06 (Dentsply) was used for root canal instrumentation. All teeth were irrigated with 3 ml of 2.5% NaOCl (Onemed Medicom, Surabaya, Indonesia) using a 30-gauge side-vented needle (Ultradent, Jordan, MN, USA) throughout instrumentation. Sonic activation (Dentsply) and 17% ethylenediaminetetraacetic acid (EDTA; Meta Biomed, South Korea) were used for final irrigation.

The teeth were randomly divided into two groups: Group 1 teeth were obturated using cold lateral compaction with the single-cone technique, while Group 2 teeth were obturated using warm vertical compaction with the continuous-wave technique (SybronEndo, Orange, CA, USA). The root canals were dried using tapered paper points and then filled with gutta-percha (Dentsply) X5 50/06 and BioRoot™ (Septodont, Saint-Maur-des-Fosses, France) according to the manufacturer's instructions. The teeth were restored using Cavit G (3M, USA) and kept at 37°C in 100% relative humidity for 48 h to ensure complete setting of the sealer.

Each root was embedded in a custom-made resin mold in a vertical position. After the resin set, two 2-mm-thick horizontal sections were cut 7–11.75 mm from the apex using a circular diamond disc, resulting in 16 specimens per group. The middle third of the root was used as the specimen to obtain a rounded root canal cross-section and to ensure that the sealer is evenly distributed. If a section revealed a root canal with isthmuses, an oval root canal, or voids in the obturation, the specimen was discarded and replaced by a new set; this occurred in only two teeth.

Push-out bond strength test

For each specimen, the dislodgement resistance was measured and the mode of failure evaluated. The specimens were subjected to a compressive load using a universal testing machine (Shimadzu, Kyoto, Japan) at a crosshead speed of 1 mm/min and a cylindrical plunger with a 0.6-mm-diameter to apply the vertical load onto the gutta-percha core; the tip's diameter was dimensioned according to the gutta-percha point to ensure equal distribution of the load on 60–80% of the gutta-percha cone-diameter without touching the sealer and specimen. That is, the plunger tip diameter was 0.6 mm, the plunger tip contacted ~60% of the gutta-percha area, and the plunger tip – gutta-percha diameter ratio was <0.85 mm, as suggested by Chen *et al.* and Donnermeyer *et al.* A push-out force was applied apicocoronally until bond failure occurred, which was manifested by extrusion of the gutta-percha core and a sudden drop along the load deflection. A graph of the applied load was generated using software, and failure was automatically determined. The failure load was recorded in Newtons (N), and the push-out bond strength of each specimen was calculated and expressed in N/mm^2 (MPa).

Mode of failure test

The mode of failure between sealer and dentine was examined under a stereomicroscope camera at ×30 magnification. Each specimen was evaluated and classified into one of three failure modes, as described by Skidmore *et al.*:

- Adhesive failure, no material left on the root canal wall
- Cohesive failure, material present on the entire root canal wall
- Mixed failure, material in patches on root canal wall.

Statistical analysis

According to the Shapiro–Wilk test, data were not distributed normally (p<0.05), so statistical analysis of the push-out bond strength was performed using the Mann–Whitney U test (p<0.05). The mode of failure was analyzed using the Chi-square test.

RESULTS AND DISCUSSION

All specimens showed measurable adhesion to root dentine. Group 1 had a significantly higher median push-out bond strength (20.91; p<0.05; standard deviation [SD] = 2.44) compared to Group 2 (Table 1). The high push-out bond strength was assumed to be due to the release of calcium hydroxide from the sealer. The mode of failure in Group 1 was a cohesive failure, while in Group 2 was a mixed failure with predominantly cohesive failure, as shown in Table 2 and Fig. 1.

Studies on the push-out bond strength of BioRoot™ are still limited. A sealer's bioactivity determines the quality of root canal obturation [15]. In general, shear bond strength and microtensile bond strength tests are widely used to evaluate the effectiveness of a dental material [16]. The microtensile bond strength test is commonly used in dentistry, but it is unreliable when using the root canal as a specimen because of a high percentage of premature bond failure and variation in test results [15]. Push-out bond strength and planar interface tests are part of the shear bond strength test [16]. The push-out bond strength test is reproducible and easy to interpret, which is why we used it [16]. The universal testing machine can analyze the minimum value of the bond strength and can use root canal specimens [16].

Table 1: Comparison of push-out bond strength between Groups 1 and 2 (MPa)

	n	Median	Min.–Max.	p-value
Group 1	16	19.6500	4.5–41.1	0.001
Group 2	16	8.7100	4.12–24.25	

*Mann–Whitney U test (p<0.05)

Table 2: Mode of failure during dislodgement in Groups 1 and 2

	Cohesive failure (%)	Mixed failure (%)	p-value
Group 1	16 (100)	0	0.043
Group 2	11 (68.8)	5 (31.3)	

*Chi-square test (p<0.05)

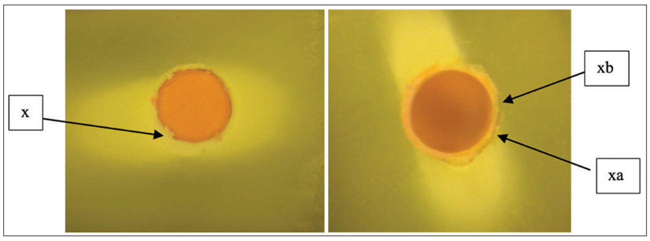

Fig. 1: Stereomicroscopic images (×30 magnification) for analysis of the mode of failure. (a) Example of Group 1 and (x) appearance of cohesive failure between sealer and dentin. (b) Example of Group 2, (xb) appearance of adhesive failure between sealer and dentin and (xa) appearance of cohesive failure between sealer and dentin

Eliminating the smear layer can strengthen the bond and minimize microleakage between a root canal and sealer [1]. However, previous studies on push-out bond strength showed variation in test results because of different protocols used [15]. Factors that affect the push-out bond strength include the root canal diameter and taper after instrumentation, the type of obturation (cold or warm vertical compaction), the root canal area, width of the specimen, load, and speed of the test [15].

The most crucial factors in the push-out bond strength test are the diameter of the plunger tip used and the diameter of the specimen [15]. Chen *et al.* reported that a plunger tip diameter <0.6 mm and >0.85 mm affects the push-out bond strength and suggested that the plunger tip diameter, based on the plunger tip – gutta-percha diameter ratio, should be <0.85 mm [15]. In contrast, Pane *et al.* showed that a plunger tip diameter >0.85 mm does not affect the push-out bond strength [17]. Donnermeyer *et al.* reported that the plunger tip should contact 60%–85% of the gutta-percha area so that the load is evenly distributed [18].

According to Skidmore *et al.*, a specimen should be ±1 mm thick to prevent uneven load distribution [19]. In this study, the 2 mm thickness of the specimen used might be why the push-out bond strength differed in Groups 1 and 2. This finding was in agreement with those of several authors who also used 2-mm-thick specimens; although the results varied, statistically, the SD was low [14,16].

Donnermeyer *et al.* were the first to analyze the push-out bond strength of calcium silicate-based sealers using the single-cone technique [18]. The mean push-out bond strength of BioRoot™ using the single-cone technique in previous and the present study was quite different because of different study protocols used: Specimen and instrumentation technique. The bond strength between BioRoot™ and the root canal was strong, which could be explained by the mode of failure in previous and the present study: Mixed versus cohesive failure.

Camilleri reported that heat produced during warm vertical compaction affects the physical properties of a calcium silicate-based sealer but not its chemical properties [13]. In the initial setting, BioRoot™ releases calcium hydroxide in both cold and warm vertical compaction. Carmona *et al.* reported that the released calcium hydroxide stimulates biomineralization in the interfacial layer of the sealer and root canal and affects the push-out bond strength [6]. The low push of bond strength of warm vertical compaction might be due to the calcium hydroxide released only in the pre-induction phase, 1 min after the sealer liquid and powder are mixed. It is still unclear whether the calcium hydroxide continues to be released until the Pasca-acceleration phase, 30 h after the sealer liquid and powder are mixed. The heat produced during warm vertical compaction also accelerates the sealer's setting time and affects the sealer's film particles. According to ISO 6876, the film particle size should be <50 μm to obtain good flow and to positively influence sealer penetration into dentin tubules.

Obturation with a monoblock system is still under development since obturation using gutta-percha and a sealer as the gold standard still does not provide a complete dentinal seal [16]. Patil *et al.* reported that the push-out bond strength of AH Plus with cold lateral compaction is higher compared to Resilon/Epiphany, with a mean value of 1.49 and a SD of 0.16 [14].

The results of this study were confirmed by Gade *et al.*, who analyzed the mode of failure of EndoSequence BC using warm vertical compaction and the single-cone technique [14]. The mode of failure of the single-cone technique was a cohesive failure, while that of warm vertical compaction was a mixed failure. The lack of adhesive failure in both studies showed that regardless of the obturation technique used, calcium silicate-based sealers have a good adhesion to the root canal.

CONCLUSION

The push-out bond strength of cold lateral compaction is higher compared to warm vertical compaction. Cold lateral compaction shows cohesive failure, while warm vertical compaction shows mixed failure but predominantly cohesive failure.

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