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Original Article

Effect of Different Tapered Gutta-Percha Points on Push-Out Bond Strength of Two Root Canal Sealers

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Abstract

Objective The purpose of this study was to compare the push-out bond strength of root canal filling with different tapered gutta-percha points of two root canal sealers.

Methods One hundred and twenty mandibular premolar teeth were prepared with a Reciproc blue file to size R50 and divided into four groups ($n = 30$ per group), with group 1 receiving iRoot SP with 02-tapered gutta-percha point (iRoot02), group 2 receiving iRoot SP with match-tapered gutta-percha point (iRoot50), group 3 receiving canal sealer bioactive glass (CS-BG) with 02-tapered gutta-percha point (BG02), and group 4 receiving CS-BG with match-tapered gutta-percha point (BG50). All samples were stored at 37°C and 100% humidity for 1 week. The specimens were resected at 3.5 and 5 mm from the apex, and push-out bond strength was measured using a universal testing machine.

Results iRoot02 had the highest push-out bond strength and differed significantly from iRootR50. BGR50 produced the lowest push-out values and showed no difference from BG02.

Conclusions The amount of iRoot SP in the root canal filling influences the material's resistance to pushing out. It will be more resistant if the ratio of iRoot SP to gutta-percha is high. When gutta-percha points with different tapers were used, the amount of CS-BG had no effect on the push-out force.

Keywords
- bioactive glass–based sealer
- calcium silicate–based sealer
- endodontic sealer
- push-out bond strength
- root canal filling

Introduction

The successful outcome of root canal treatment relies significantly on the accomplishment of both thorough disinfection of the root canal system and complete obturation of the root canal in three dimensions.[1,2] Significant efforts have been made with the goal of choosing suitable materials for root canal obturations; however, none have successfully exhibited every aspect of ideal properties as proposed by Grossman.[3] Nonetheless, the deployment of a unique root canal sealer composed of calcium silicate has resulted in a significant advancement. The application of calcium silicate–based sealers (CSS) has dramatically changed the fundamental concepts underlying conventional root canal filling methods. In the past, a method of applying gutta-percha points in conjunction with sealers involved an attempt to exert maximal compression on the gutta-percha inside the root canal, thereby minimizing the available space for the traditional

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sealers. This approach aimed to solve the inherent drawbacks associated with sealers, which tend to undergo shrinkage during the process of setting.[4] This reduces the chance of leakage of the root canal filling material. In contrast, CSS slightly expands during the setting process, which reduces the necessity of minimizing the quantity of sealer used to seal the root canal.[5,6] The concept of filling the root canal with a single cone technique was subsequently reintroduced to be used in conjunction with CSS.[7]

The term "single cone technique" has a negative connotation when used in conjunction with traditional sealers for root canal obturation.[8,9] Consequently, when applied to CSS, new terminologies for these techniques were developed, such as sealer-based techniques, hydraulic condensation techniques, and passive compaction techniques.[7,10] The present technique involves the application of a single gutta-percha point in conjunction with CSS for root canal filling without exerting pressure in the root canal system. The application of heat is unnecessary except during the process of cutting the gutta-percha point at the orifices. This approach reduces both the duration of the procedure and the physical strain experienced by the patient and the operator.[11]

The composition of CSS primarily consists of approximately 50% tri- and di-calcium silicate, with an additional 35 to 45% inclusion of either zirconium oxide or tantalum oxide as an opacifier.[12] The properties of this substance exhibit a closer resemblance to the ideal characteristics compared to traditional root canal sealers. It demonstrates slight expansion during the setting process, possesses low solubility, exhibits biocompatibility, shows minimal cytotoxicity, maintains a high pH level, and demonstrates osteoconductive, osteoinductive, and cementogenic properties. Additionally, CSS demonstrates superior or equivalent sealing abilities to traditional root canal sealers.[13,14] However, there are still drawbacks. The hardness of CSS can pose significant challenges in situations requiring retreatment or postspace preparation, as it becomes a greater obstacle to removal.[15–17]

Recently, a novel bioactive glass–based sealer (BGS) primarily composed of insoluble fatty acid salts and bioactive glass filler has been developed.[18] BGS primarily consists of insoluble fatty acid salts, with the addition of bioactive glass fillers. The material consists of two pastes: paste A contains fatty acids, bismuth subcarbonate, and silica dioxide, while paste B is composed of magnesium oxide, calcium silicate glass (bioactive glass), and silica dioxide.[18] It exhibits various essential characteristics, resulting in suitable materials for endodontic applications. Its main characteristics include physicochemical stability, biocompatibility, and excellent sealing abilities, which are key to effective root canal treatments. Physicochemically, BGS exhibits excellent physical properties according to ISO standards for root canal sealers. It has a flow rate of 28.7 mm, a working time of 15 minutes, and a setting time of 180 minutes, with a film thickness of 27.9 µm.[19] BGS exhibits a slightly alkaline pH of approximately 10, facilitating the formation of hydroxyapatite (HAp) on its surface, which enhances bonding to dentin. Both in vitro and in vivo studies using human periodontal ligament cells and osteoblast-like cells demonstrated the absence of cytotoxicity, while BGS facilitated cell migration and proliferation.[19] BGS demonstrates a superior sealing ability. This sealer significantly decreases leakage relative to traditional sealers and forms HAp-like tags that infiltrate dentinal tubules, thereby improving the seal between the material and the canal walls.[20] In addition, it is resilient enough to facilitate removal from the root canal, if necessary.[21] The single cone technique can be applied effectively for root canal obturation.[22]

The classification of gutta-percha points used for the purpose of filling root canals is often based on their taper. There are two different types of gutta-percha points: ISO-standardized (0.02 taper) gutta-percha points (ISO-GP) and nonstandardized gutta-percha points.[22] The ISO-GP type allows more sealers to be accommodated within the root canal in comparison to an alternative type of gutta-percha. A reduced interface between gutta-percha and sealer corresponds to a decreased likelihood of leakage.[23,24] At present, there is a lack of comparative research aimed at assessing the results of root canal filling techniques using CSS materials in conjunction with gutta-percha points of various tapered diameters. The main objective of this study is to compare the push-out bond strength of root canal fillings using two different types of CSS and tapered gutta-percha points.

Materials and Methods

Ethics

This study was approved by the Local Research Ethics Committee with COA no. RSUERB 2022-039.

Sample Selection

A total of 120 human mandibular premolars, which were extracted for orthodontic purposes, were obtained and preserved in a 0.1% thymol solution. The roots that were chosen were subjected to radiographic examination in both the mesiodistal and buccolingual views to verify the presence of a single root canal that is straight and round, without any calcification. It was ensured that the difference in canal width between the two views did not exceed 1 mm.

Sample Preparation

The crowns were decoronated using a diamond disk on a straight handpiece and copious water cooling to attain a standard length of 13 mm for each tooth. Size 10 K-files were inserted into each root canal through the apical foramen to establish apical patency and confirm that the canal's apical size matched the size 10 or 15 K-file. If the criteria were not met, the sample were be excluded. The determination of the working length involved subtracting 1 mm from the apical foramen. The root canal was prepared using the Reciproc Blue system (VDW GmbH, München, Germany) to a size R50 by the same operator. Each time the file was pulled out from the root canal for the purpose of cleaning, a volume of 2 mm of a sodium hypochlorite solution (NaOCl) with a concentration of 2.5% was used for irrigation of the canal. The solution was delivered using a 30-gauge side-vent needle tip inserted

2 mm short of the working length. The final rinse involved using 2 mL of 17% EDTA solution for 1 minute per root canal, followed by 5 mL of 2.5% NaOCl. Subsequently, the root canal was dried using an absorbent paper point. The sample was further divided into four groups in a random manner, based on the types of root canal sealers and the taper of gutta-percha points.

- **Group 1** received iRoot SP with 0.02 tapered gutta-percha point (iRoot02: $n = 30$). The canals were filled with a size 50/0.02 gutta-percha point and iRoot SP (Innovative Bioceramix, Vancouver, Canada). The sealer was first inserted into the middle of the canal using an intracanal tip. The gutta-percha point was then gently introduced to the working length after being covered in a thin layer of iRoot SP. Following the removal of the gutta-percha cone at the orifice level, it was carefully compressed vertically using a plugger.
- **Group 2** received iRoot SP with matched-taper gutta-percha points size R50 (iRoot50: $n = 30$). The obturating procedure in group 2 was performed similarly to that of group 1, except for the use of a matched-taper gutta-percha cone of size R50.
- **Group 3** received Nishika Canal Sealer Bioactive Glass (CS-BG) with 0.02 tapered gutta-percha point (BG02: $n = 30$). The canals were filled with a size 50/0.02 gutta-percha point and CS-BG (Nippon Shika Yakuhin, Yamaguchi, Japan). In the beginning, the root canal wall was coated with a CS-BG using an R50 rotary file. Subsequently, the gutta-percha point size R50 was coated with CS-BG and gradually inserted into the working length. Subsequently, a plugger was used to gently compress the gutta-percha cone in a vertical manner subsequent to its cutting at the level of the orifice with heat instrument.
- **Group 4** received CS-BG with matched-taper gutta-percha point size R50 (BG50: $n = 30$). The obturating procedure in group 4 was performed similarly to that of group 3, except for the use of a matched-taper gutta-percha cone of size R50.

Prior to the push-out bond strength test, the specimens were kept for a week at 37°C and 100% humidity in an incubator.

Push-Out Bond Strength Test

A low-speed precision cutting machine (IsoMet 4000; Buehler, Lake Bluff, IL, United States) was used to cut the samples perpendicularly with 1.5-mm thickness. The cuts were made at 3.5 and 5 mm from the working length. Using a universal testing machine, the push-out force that displaced the materials from the canal was determined. A metal base with 2.5-mm-diameter holes provides a platform for the specimen. To apply the force vertically to the obturation material, stainless-steel plunger with a 0.5-mm diameter was used. The samples were positioned at the center of the hole on the support base using loupes with a 3X magnification. The plungers proceeded to apply the load in an apicocoronal direction over the filling materials at a crosshead speed of 0.5 mm/minute (►**Fig. 1**).

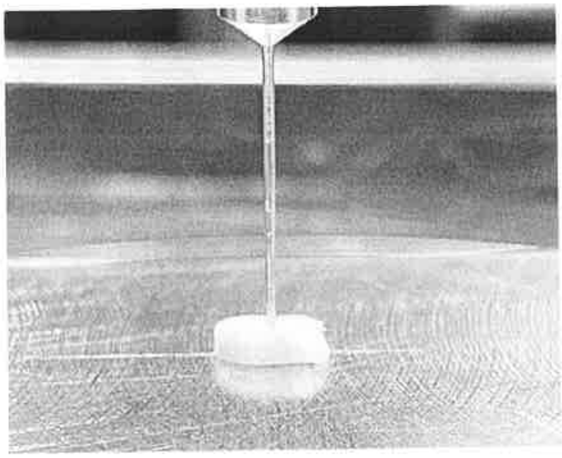

Fig. 1 The installation of a sample for a push-out bond strength test with a universal testing machine

The thickness of each sample was measured three times by a digital vernier caliper, and the measured values were averaged and recorded. The diameter of each sample's apical and coronal cross-sectional surfaces was measured twice under a stereomicroscope (Nikon MM-22 Measuring Microscope with SC-112 digital counter). The data were averaged and recorded (►**Fig. 2**).

The maximum value of the force in newtons (F-max) at which the materials became detached was recorded, and the calculation of the push-out bond strength was performed using the following equation:

$$P = \frac{F\text{-max}}{A},$$

where P = push-out bond strength (MPa) and *F*-max = maximum force.

The calculation of the adhesion surface area was performed using the following equation:

$$A = \pi(r_1 + r_2)\sqrt{(r_1 - r_2)^2 + h^2},$$

where A = adhesion surface area, $r_1 = \frac{\text{coronal diameter}}{2}$, $r_2 = \frac{\text{apical diameter}}{2}$, $\pi = 3.14$, and h = the section thickness.

Statistical Analysis

The data were subjected to analysis using SPSS 24.0 (SPSS Inc., Chicago, IL, United States). The normality of the variants in each experimental group was assessed using the Kolmogorov–Smirnov test, while the homogeneity of these variants was tested using Levene's test. The values of push-out bond strength exhibited a normal distribution. Nevertheless, the assumption of homogeneity of variance was not achieved. As a result, the mean difference between groups was assessed using Welch's analysis of variance (ANOVA), followed by multiple comparisons using Dunnett's T3 test. The predetermined level of significance was established at 0.05.

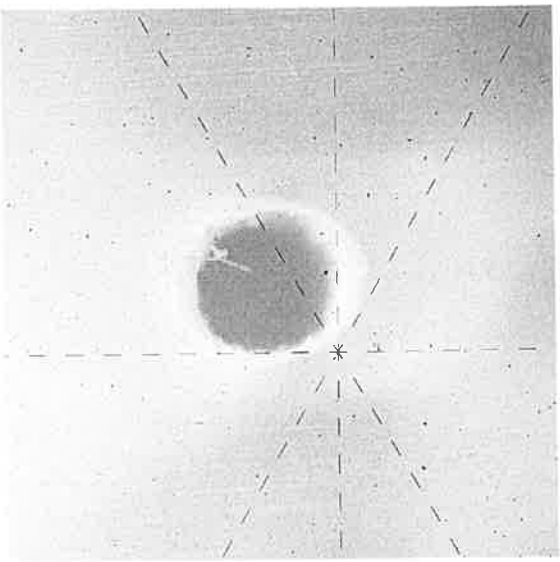

Fig. 2 The diameter of each sample's apical and coronal cross-sectional surfaces was measured under a stereomicroscope.

Ethical Considerations

This study was approved by the Ethics Review Board of Rangsit University (RSU-ERB) with COA no. RSUERB 2022-039.

Results

The push-out bond strength of each group is shown in ►**Fig. 3**. The iRoot02 group exhibited the highest push-out bond strength, while the BG50 group demonstrated the lowest push-out bond strength. When conducting a multiple comparison of the means between the experimental groups (►**Table 1**), it was observed that the iRoot SP groups had significantly higher values compared to both the CS-BG groups. Following individual evaluation of each sealer type, it appeared that the iRoot SP groups, specifically iRoot02, exhibited significantly higher push-out bond strength values compared to iRoot50. On the other hand, there was no difference between the BG02 and BG50 groups.

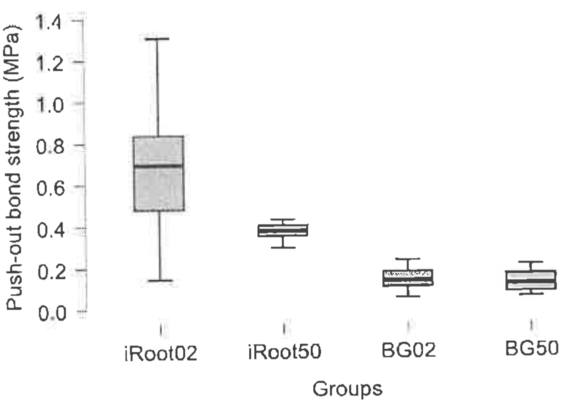

Fig. 3 Push-out bond strength values of each group.

Discussion

The push-out bond strength of the iRoot SP groups was found to be significantly higher than that of the CS-BG groups in this study. This could be because the major components of the sealer differ. iRoot SP is a CSS that belongs to the hydraulic cement family, whose main component is calcium silicate.[25] CSS forms calcium silicate hydrate gel and calcium hydroxide when mixed with water.[26] The hardness of the material will progressively increase over time following the hardening process. A study has indicated that CSS has a high level of compressive strength, usually within a range of 100 to 200 MPa.[27] In addition, a comparative study was conducted to assess the compressive strength of iRoot SP and CS-BG. The results indicated that iRoot SP exhibited a compressive strength of 8.58 ± 2.42 MPa, while CS-BG demonstrated a compressive strength of 4.62 ± 1.70 MPa. Significantly, the compressive strength of iRoot SP was much higher than that of CS-BG.[28] The major component of CS-BG is insoluble fatty acid salt, with bioactive glass as a filler distributed entirely within the material. As a result, it is less rigid, making it easier to apply force to remove the material from the root canal than in iRoot SP.

The type of gutta-percha point used influences the push-out bond strength. For the iRoot SP groups, 0.02 tapered gutta-percha points had a smaller cross-sectional area than match-tapered gutta-percha points at all levels except D_0. This led to a higher sealer/gutta-percha ratio and a much higher push-out bond value. Conversely, within the CS-BG groups, variations in the taper size of the gutta-percha points did not have a significant effect on the push-out bond strength. The results showed that the amount of sealer used influenced root canal retention in the iRoot SP groups, but had no effect on the CS-BG groups.

In the present study, the specimens were prepared by perpendicularly cutting off the roots at 3.5 and 5 mm from the apex, resulting in a thickness of 1.5 mm. Typically, this level represents the end of postspace preparations for tooth restoration.[29,30] It is hence the area that is most impacted when root canal filling material is removed during the postspace preparation procedure. Application of CSS in conjunction with a 2% taper gutta-percha point is expected to effectively preserve the sealing of apical root canal filling when postspace preparation is required. The findings of this study correspond with the results of the apical microleakage study, which concluded that the timing of postspace preparation does not have an impact on apical microleakage when the root canal is filled with CSS using a single cone technique.[31]

The diameter of the plunger used in the push-out test was 0.5 mm, whereas the diameter of the root canal shaped with a Reciproc blue file size R50 at 3.5 mm from the tip was 0.67 mm. Consequently, the plunger's diameter was slightly smaller than the cross-section area of the specimen's root canal. When using a 0.02 taper gutta-percha point to fill the

Table 1 Push-out bond strength values of each group

Type of sealers	Taper of gutta-percha cone	Push-out bond strength (MPa), mean ± SD
iRoot SP	ISO	0.6652 ± 0.3130^a
	Matched taper	0.3719 ± 0.0400^b
Nishika canal BG	ISO	0.1453 ± 0.0485^c
	Matched taper	0.1242 ± 0.0445^c

Abbreviations: BG, bioactive glass; SD, standard deviation.
Note: Means sharing the same superscript are not significantly different from each other ($p \geq 0.05$).

root canal, the plunger tip touches both the surface of the gutta-percha and the sealer at the same time. In contrast to the group filled with a match taper, it might solely touch the gutta-percha, causing a variation in the force used to remove the material from the canal. From a plunger diameter point of view, the interface between gutta-percha and sealer may affect push-out bond strength values in groups using match-tapered gutta-percha points, while the sealer–dentin interface has a greater influence on groups using 0.02 taper gutta-percha points.

Both iRoot SP and CS-BG could infiltrate the dental tubule and precipitate to form HAp.[20] The CS-BG matrix generates a pH of approximately 10 in the dental fluid at the sealer–dentin interface, which initiates the mechanism of CS-BG bonding to the dentinal root canal wall. Following that, the CS-BG matrix exhibits an amphiphilic characteristic, facilitating the growth of HAp. Finally, HAp crystals grow into the dentinal tubule.[18] The presence of HAp-like structures within dentinal tubules contributes to the improvement of the sealability of root canal fillings and could assist in the material's resistance to push-out forces. Nevertheless, it ought to be recognized that CS-BG exhibits lower strength compared to iRoot SP, rendering it less capable of enduring push-out forces. Specifically, iRoot SP demonstrates about twice the strength of CS-BG.[28]

The specimens were kept for 7 days to allow the sealers to harden completely before being evaluated for push-out bond strength. The compressive strength of the calcium silicate cement might have additionally developed until it reached its maximum level at 28 days.[32,33] It is probable that the push-out bond strength value in the iRoot SP group will increase over time. Data on the change of compressive strength values over a period of time are not available for BGS. As a result, additional studies should be conducted in the future.

Conclusion

The push-out bond strength of root canal filling with gutta-percha point combined with CSS was shown to be higher compared to that of BGS. In the case of CSS, it was evident that the use of gutta-percha points with a smaller taper resulted in higher push-out bond strength compared to the use of match-tapered gutta-percha points. However, it was found that the push-out bond strength remained similar for BGS, regardless of the taper size of the gutta-percha points used.

Highlights

- When used in conjunction with CSS, the push-out bond strength of small, tapered gutta-percha points is greater than match-tapered gutta-percha points.
- There is no difference in the push-out bond strength of small-tapered and match-tapered gutta-percha points when using BGS.
- CSS exhibit a higher push-out bond strength in comparison to BGS.

Artificial Intelligence–Assisted Technologies

The authors declare no use of AI in the production of the submitted article except for grammar checking.

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Conflict of interest

None declared.

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