Review Article

Design Variability of the Push-out Bond Test in Endodontic Research: A Systematic Review

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Abstract

Introduction: There is limited literature on the impact of testing variables on the push-out bond test (POBT). This review identified designs of the POBT used in the endodontic literature and aimed to determine which experimental variables may influence the push-out bond strength (POBS). **Methods:** A systematic review based on PRISMA guidelines was performed by searching the PubMed, SCOPUS, and Cochrane library databases using terms including *push-out* and *dislocation resistance* and descriptions of endodontic materials. Test variables assessed included method of root preparation, timing of sectioning compared with filling, thickness, diameter and taper of sections, and plunger size and velocity. The POBS of 3 common materials (gutta-percha and AH Plus, mineral trioxide aggregate, and Biodentine) were collected from investigations, and a comparison was attempted. **Results:** One hundred thirty-three studies assessed the POBS of root-filling materials, 68 assessed root repair cements/root-end filling materials, and 16 assessed orifice barrier materials other than mineral trioxide aggregate. There was significant variation in all of the assessed variables, resulting in a large range of reported values for the POBS of the various materials. Because of this heterogeneity in study design, no further statistical analysis of the impact of the test variables on POBS was possible. **Conclusions:** There was considerable variation in the POBT design used in endodontic research. Greater standardization is required for future research as well as accurate reporting for all test variables to assess the impact of specific design variables on POBS. *(J Endod 2018;■:1–9)*

Key Words

Biodentine, bond strength, dislocation resistance, MTA, root filling

Significance

The push-out bond test provides information predicting the clinical performance of endodontic materials. This review confirmed that the great variability in the test criteria raises doubt about the test's validity and calls for greater standardization of the associated variables.

The push-out bond test (POBT) has been widely used in endodontic research to evaluate the push-out bond strength (POBS) of various materials. The POBS may be assumed to predict clinical performance, but there is no evidence to support this. Materials that have been tested are those that are used clinically to fill the canal space, including posts (1), root fillings (2, 3), root repair cements (4), root-end fillings (5), and orifice barriers (6).

The main advantage of the POBT over other bond testing methods (including shear and tensile bond tests) is the ability to test a material within a canal surrounded by dentin, thus reflecting the clinical use of the material (7). However, the setup of the POBT is such that there are numerous variables that differ from study to study and may affect the bond test measurements, leading to concerns in the interpretation of results and precluding any meaningful comparison of POBS measured in different studies (8). These variables include method of tooth preparation, timing of root filling, plunger diameter, and properties of the root-filling material itself (including stiffness, diameter, and taper).

The significance of this variation in test design is that it may preclude the comparison of POBS data measured by different research groups. Determining which variables have a significant impact on bond strength measurements would allow researchers to better interpret existing literature, reconcile seemingly contradictory results, and design future experiments in such a way as to ensure both reliability and reproducibility.

Hence, the aim of this systematic review was to identify POBT setups that have been used in the evaluation of endodontic materials to determine which variables can affect POBS measurements.

Materials and Methods

Search Rationale

This study was conducted and reported according to the PRISMA Statement (www.prisma-statement.org). The strategy was to identify articles that used the POBT on endodontic materials (eg, root filling, root repair cement, or base material). The only exclusion criterion was studies that did not measure the dislodgment resistance (N) of endodontic materials to radicular dentin in a POBT design. The main focus of the review was root-filling materials, including core materials (eg, gutta-percha [GP] or Resilon [Resilon Research, Madison, CT]) and root canal sealers. Other materials included root repair and pulp-capping cements (which have also been

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used as root-end filling materials) such as mineral trioxide aggregate (MTA), calcium enriched mixture (CEM) (BioniqueDent, Tehran, Iran), Biodentine (Septodont, Saint-Maur-des-Fosses, France), Cavit (3M ESPE, Seefeld, Germany), and intermediate restorative material (IRM) (Dentsply, Milford, DE) as well as orifice plug materials used to prevent coronal leakage (9, 10) including polycarboxylate and glass ionomer cements. The rationale for assessing these materials in addition to root fillings was that they share a similar function as root fillings (ie, sealing), and hence, bond strength would also be a desirable property. Post and luting cements were excluded from this review.

Search Strategy

Three separate searches were performed of the PubMed, SCOPUS, and Cochrane library databases in March 2018, combining general descriptors of the POBT with specific terms for root fillings, root repair cement, and orifice barrier materials.

The exact search terms used for each group were the following.

Root filling and sealer terms:

- Push-out bond OR push-out test OR push-out strength OR dislocation resistance
- AND endodontic* OR root OR root canal
- NOT post

Root repair cements/root-end fillings search terms:

- Push-out bond OR push-out test OR push-out strength OR dislocation resistance
- AND MTA OR mineral trioxide aggregate OR CEM OR calcium enriched mixture OR bioceramic OR bioaggregate OR cavit OR IRM OR interim restorative material OR calcium silicate OR Biodentine

Orifice barrier materials:

- Push-out bond OR push-out test OR push-out strength OR dislocation resistance
- AND glass ionomer OR polycarboxylate OR orifice plug OR orifice barrier OR resin composite OR Biodentine
- NOT post

No restrictions were placed on the year of publication. Gray literature was not searched; only articles published in peer-reviewed journals were considered. The abstracts were scanned for relevance (ie, studies that actually performed the POBT on 1 or more endodontic materials), and relevant articles were included in the review. Reference lists of included articles were read, and new articles were identified and included if relevant. EndNote (X7.0.2 Bld790, Researchsoftware.com, Haarlem, Netherlands) was used to manage references for the review.

Data Extraction and Analysis

Because it is well-established that the material being tested affects the measured POBS (11), data analysis was limited to studies using the same materials. The 3 most commonly investigated materials in the literature (GP and AH Plus, MTA, and Biodentine) were chosen to assess the impact of testing variables on POBS measurements.

Data were extracted by a single reviewer (J.B.). Test variables collected from the studies included method of root preparation, timing of sectioning compared with filling, thickness, diameter and taper of sections, and plunger size and velocity. In investigations where there were numerous groups that contained the 3 materials of interest, the control group (ie, unexposed to any experimental variable) was chosen. Where samples were available from multiple root thirds, those from the middle third were chosen. Where no true control group was used, a judgment was made as to which group most closely resembled those used as a control in other studies.

Articles were in data extraction if they measured the dislodgment resistance of one of these materials to radicular dentin and presented their data in a format that was readily extractable (ie, not only graphical representation). The exclusions were as follows:

Root filling and sealer:

- Two hundred thirteen screened/assessed, 80 excluded (133 remaining for qualitative synthesis), 60 included for attempted quantitative analysis

Root repair cements/root-end fillings:

- One hundred forty-two screened/assessed, 74 excluded (68 remaining for qualitative synthesis), 52 included for attempted quantitative analysis

Orifice barrier materials:

- One hundred four screened/assessed, 88 excluded (16 remaining for qualitative synthesis), 14 included for attempted quantitative analysis.

Results

Root-filling Materials

One hundred thirty-three articles used the POBT to evaluate the bond strength of various root-filling materials. The majority of articles published before 2010 focused on comparisons between methacrylate- and epoxy resin–based sealers (8, 12–15). Other articles centered their investigation around the effects of various factors on bond strength including the impact of various irrigation protocols (16–19), laser activation protocols (20–22), or the impact of residual medicaments (23–25). More recent publications have included a comparison of calcium silicate–based sealers, such as iRoot SP (Innovative Bioceramix, Vancouver, Canada), MTA Fillapex (Angelus, Londrina, PR, Brazil), and EndoSequence BC sealer (Brasseler USA, Savanah, GA), with epoxy resin–based sealers (26–28).

In terms of the POBT design itself, the following variables were assessed.

Method of root preparation. With several exceptions (7, 29–32), most studies used the natural canal to test their material of choice, enlarging it with high-speed burs (parallel or tapered), Gates-Glidden drills, or rotary nickel-titanium (NiTi) instruments. The exceptions prepared artificial canals in the dentin around the natural canal.

Timing. When NiTi instruments were used in 101 of 103 studies (98%), the root canal was filled before slicing/sectioning. When burs were used in 22 of 30 studies (74%), the root filling was more commonly completed after sectioning.

Thickness, diameter, and taper. The thickness of slices varied between 1 and 8 mm in 133 studies. Studies that used a thickness of less than 4 mm (93%) described their test method as a thin-slice POBT. A significant proportion used thicknesses greater than 1 mm (34%), most commonly 2 mm (22%). The diameter of the canal was specified only in cases where burs were used for preparation and varied between