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The correlation between fluid transport and push-out strength in root canals filled with a methacrylate-based filling material

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Abstract

Moinzadeh A-T, Mirmohammadi H, Hensbergen IAM, Wesselink PR, Shemesh H. The correlation between fluid transport and push-out strength in root canals filled with a methacrylate-based filling material. *International Endodontic Journal*, **48**, 193–198, 2015.

Aim To investigate the correlation between fluid transport and dislocation resistance in canals filled with a methacrylate-based filling material.

Methodology The root canals in sixty-five single-rooted human teeth were prepared to size 40, 0.06 taper. Sixty roots were filled with a single-cone technique using RealSeal SE sealer and divided into 3 groups, whilst five roots served as fluid transport positive control. Group 1 ($n = 20$): correlation group. Specimens were consecutively tested with fluid transport for 90 min and thereafter with the push-out test at coronal and apical root levels. Group 2 ($n = 20$): push-out control. Specimens were only subjected to the push-out test at coronal and apical root levels. Group 3 ($n = 20$): fluid transport negative control. Specimens were totally covered with nail varnish. The

correlation between fluid transport and dislocation resistance was assessed by Kendall's tau-b coefficient. The Mann–Whitney U-test was used to compare dislocation resistance between groups 1 and 2 and fluid transport between groups 1 and 3. Significance level was set at $P < 0.05$.

Results Kendall's tau-b correlation coefficients between fluid transport and dislocation resistance were weak, being coronally 0.139 ($P = 0.444$) and apically -0.080 ($P = 0.658$). No significant difference in dislocation resistance could be detected between groups 1 and 2 at both root levels ($P = 0.052$ and $P = 0.336$, respectively).

Conclusion No significant correlation could be identified between fluid transport and dislocation resistance, meaning that the coronal-apical sealing ability of a methacrylate-based root canal filling is independent of its adhesive properties as indicated by its dislocation resistance.

Keywords: adhesion, dislocation resistance, fluid transport, push-out, root canal filling, seal.

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Introduction

A root filling is expected to perpetuate the microbial control achieved by the disinfection protocols and should therefore prevent microleakage. Several *in vitro*

leakage models have been designed to evaluate the sealing ability of root filling materials (De Bruyne *et al.* 2005a,b), and the fluid transport model is able to detect the presence of continuous pores connecting both extremities of the root canal (De Bruyne *et al.* 2005a,b, Shemesh *et al.* 2007, De-Deus *et al.* 2008). Another property of root filling materials that is of potential importance is their adhesion ability, as demonstrated by numerous studies (Gesi *et al.* 2005, Nagas *et al.* 2011, Carneiro *et al.* 2012, Chen *et al.* 2013, Pane *et al.* 2013). This parameter is commonly

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evaluated by the push-out test and expressed as dislocation resistance values. The justifications as to why the adhesion ability of a root filling material may be relevant to endodontic outcomes are scarce. It has been assumed that occlusal loads could generate separation forces between the filling material and dentine (Bishop *et al.* 2008). Furthermore, as the necessary condition for adhesion between two dissimilar materials is their close contact (Van Van Noort 2013), it can be hypothesized that materials with high adhesive characteristics may also possess good sealing properties because of their intimate contact with dentine.

The question of whether a relationship exists between the outcomes of sealability and adhesion tests has been raised in the field of operative dentistry without a definitive answer (Fortin *et al.* 1994, Neme *et al.* 2000). Hitherto, only one study has investigated a hypothetical relationship between the fluid transport and the push-out tests on filled roots (Neelakantan *et al.* 2011). This study revealed a high negative correlation between these two methods, concluding that minimal leakage and high dislocation resistance values coincided. Such dependence would mean that root fillings with higher adhesive properties would also have better sealing ability and that adhesive properties could therefore be considered as a surrogate for sealing ability.

The aim of this study was to investigate whether any relationship exists between the sealing ability and dislocation resistance of a methacrylate-based root filling material as evaluated, respectively, by fluid transport and push-out strength tests. This was achieved by consecutively performing both tests on the same root filled teeth and calculating the coefficient correlating both measurements. The null hypothesis was that fluid transport and dislocation resistance were correlated.

Materials and methods

Sample size calculation

The G*Power (3.1.3 PC version) was used to determine the required sample size (Faul *et al.* 2009). A correlation bivariate normal model belonging to the exact family was used for *a priori* sample size estimation. The input parameters were as follows: two-tailed distribution with correlation $\rho H_1 = 0.6$, correlation $\rho H_0 = 0$, α error probability = 0.05 and power = 0.8. The minimal estimated sample size was found to be 19 with a critical value $r = 0.46$ as upper limit for accepting the null hypothesis.

Specimen selection and preparation

Sixty-five recently extracted human single-rooted teeth stored in water at room temperature were selected. Mandibular incisors and teeth with a cement–enamel junction to apex distance <15 mm were excluded. The teeth were radiographed in mesio-distal and bucco-lingual direction to confirm the presence of a single untreated canal. The bucco-lingual and mesio-distal diameters of each root canal were radiographically measured at 7 mm from the apex in order to homogeneously allocate the specimens to the different groups. The teeth were embedded in self-polymerizing acrylic resin except for the apical third and were then decoronated axially at 15 mm from their apex with a diamond-coated disc. For the specimens intended to undergo fluid transport testing, following the canal instrumentation and filling procedures, the junctions between the resin and the root were sealed with cyanoacrylate glue (Permacol, Ede, the Netherlands). Apart from the coronal access and the apical foramen, the root surface uncovered by acrylic resin was covered with two layers of nail varnish. In the fluid transport negative control group, the entire root surface uncovered by acrylic resin was covered with nail varnish.

Root canal preparation and obturation

A size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was placed inside the canal and moved apically until it was visible at the apical foramen. The working length was obtained by subtracting 1 mm from this length. The root canals were then instrumented with Mtwo rotary nickel–titanium instruments (VDW GmbH, Munich, Germany) using a torque-control motor (VDW Silver, VDW GmbH) up to a standardized shape of size 40, 0.06 taper. Rinsing was performed with 2 mL of 2% NaOCl (Dentec, IL Zoetermeer, the Netherlands) at each change of file. A final rinse with 3 mL of 17% EDTA (Vista dental products, Inter-med Inc., Racine, WI, USA) for 2 min was followed by a 3-mL rinse of distilled water. The irrigants were delivered with a 27-G open-ended needle (Neolus NN-2719R, Terumo Europe, Leuven, Belgium) placed slightly short of the binding point.

The specimens were randomly assigned to one experimental group and two control groups. Group 1 (experimental): fluid transport followed by push-out ($n = 20$). Group 2: dislocation resistance control ($n = 20$). Group 3: fluid transport negative control ($n = 20$).

The canals were then dried with paper points and filled according to the following protocol. RealSeal SE sealer (Kerr Corporation, Orange, CA, USA) was placed in the root canals by means of a 2.5-mL syringe and a capillary tip (Ultradent Products Inc., South Jordan, UT, USA) and further distributed with a size-25 EZ-Fill bidirectional spiral (EDS, S. Hackensack, NJ, USA) rotated at 300 rpm for 5 s at 3 mm from the working length. A corresponding size 40, 0.06 taper RealSeal cone (SybronEndo, Glendora, CA, USA) fitted to canal length was inserted into the canal to working length.

Five specimens were filled with a loosely fitting cone without any sealer (fluid transport positive control ($n = 5$)).

Subsequently, the specimens were placed in humid gauze and sealed in a plastic test tube at 37 °C for a week.

Wetting fluid and fluid transport measurements

A previously reported modified fluid transport model (Özok *et al.* 2013) was mounted. Fluid transport was measured by observing the movement of an air bubble entrapped within a 0.1-mL glass capillary tube (Witeg Labortechnik GmbH, Wertheim, Germany). A 50-kPa input pressure was applied to the coronal end of the root, and the resulting output pressure at the apical end was measured with the capillary tube. Galpore (Benelux Scientific, Eke, Belgium), a perfluoroether presenting a very low surface tension (16 mN m⁻¹) and a viscosity of 4.4 mPa.s, was used as the testing fluid. The fluid transport measurements were recorded at room temperature for a total of 90 min at different time-points ($t = 0, 1, 5, 15, 30, 60$ and 90 min).

Dislocation resistance by push-out strength test

Each specimen was sectioned perpendicularly to its long axis with a water-cooled, low-speed diamond saw (Isomet 1000 precision saw, Buehler; Lake Bluff, IL, USA) to prepare two slices of 1 mm thickness (at 6 and 9 mm from the apex). The thickness of the saw (300 µm) was taken into account during this process. Each slice was marked on its apical surface. The root slices were then dislodged from the embedding material, and digital callipers (Model 500-144, Mitutoyo Corp., Kawasaki, Japan) were used to measure the exact thickness of each slice. The diameters of the canal on the coronal and apical aspects of each slice were measured using a Stemi SV stereo-

scopic microscope (Carl Zeiss Microscopy GmbH, Göttingen, Germany). Each slice was then placed in a universal testing machine (Instron 6022, Instron Corporation, Canton, MA, USA). Three cylindrical stainless steel punchers of different sizes, with diameters of 0.3, 0.5 and 0.8 mm, were made available. For each slice, a puncher was chosen to cover the root filling as much as possible without touching the root canal walls. The puncher was advanced at a speed rate of 0.5 mm min⁻¹ in an apico-coronal direction until dislocation of the filling material occurred. For each section, the dislocation resistance value (MPa) was calculated by dividing the failure load (N) by the interface area (mm²) between the root canal filling and dentine. The tested sections correspond to a truncated cone, and the formula of the dislocation resistance can be calculated as follows:

$$\text{Dislocation resistance} = \frac{F}{\pi(r + R)s}$$

where the slant height, $s = \sqrt{(R - r)^2 + h^2}$

R and r being the radii of the bases of the frustum and h the slice thickness.

Statistical analysis

The data were tested for normality by the Shapiro–Wilk test and found to be non-normally distributed. Results were therefore presented as median with interquartile range. The correlation coefficients between fluid transport and dislocation resistance values (group 1) were calculated with Kendall's tau-b coefficient. The Mann–Whitney U-test was applied to assess the difference in fluid transport rate between the negative control group (group 3) and the experimental group (group 1) as well as the difference in dislocation resistance between the control group (group 2) and the experimental group (group 1). The Wilcoxon test was used to evaluate the difference in dislocation resistance between root levels. Results were considered to be significant when the P -value was <0.05 and highly significant when $P < 0.01$. Effect sizes for pairwise comparisons were reported as absolute values of Pearson's correlation coefficient r . All statistical analyses were performed using SPSS v.21 (SPSS Inc., Chicago, IL, USA), Excel 2010 (Microsoft Corp, Redmond, WA, USA) and Prism software version 4 (GraphPad Software Inc., San Diego, CA, USA).

Results

Fluid transport

The surface tension of the wetting fluid was 16 dynes cm⁻², the input pressure 50 kPa and the contact angle of the wetting fluid close to 0. According to Young–Laplace's equation, a pore can be seen as a cylindrical capillary of diameter d and P_c being the Young–Laplace's capillary pressure of the entrapped air within the pore (Laplace 1805, Young 1805):

$$P_c = \frac{4\sigma \cos \theta}{d}$$

with σ the surface tension of the liquid–air interface and θ the wetting angle with dentine. The minimal pore diameter that could be detected was of 1.28 μm . Leakage was detected in 35% of the specimens. This corresponds therefore to the percentage of the specimens presenting a continuous pore from coronal to apical with a minimal diameter equal or superior to 1.28 μm . No fluid transport could be detected for all 20 specimens of the negative control group, whereas rapid bubble movement for all five specimens of the positive control group indicated massive leakage. The median fluid transport value with corresponding interquartile range for the experimental group was 0 [0–2.33] and was found to be highly significantly different than the negative control group 0 [0–0], ($P = 0.009$, $r = 0.42$) (Mann–Whitney U-test).

Dislocation resistance

No significant difference in dislocation resistance (in MPa) could be detected between the experimental group: coronal 1.03 [0.68–1.33] and apical 1.15 [0.72–1.62], and the dislocation resistance control group: coronal 0.18 [0.05–2.28] and apical 0.41 [0.11–3.01] at both tested root levels ($P = 0.052$, $r = 0.31$ and $P = 0.336$, $r = 0.16$) (Mann–Whitney U-test), indicating no significant effect of the fluid transport on the dislocation resistance of the material. There was no difference in dislocation resistance between both tested root levels in the experimental group ($P = 0.452$, $r = 0.12$) (Wilcoxon test).

Correlation analysis

The correlation analysis between fluid transport and dislocation resistance at the different root levels provided the following Kendall's tau-b coefficients:

$\tau_{\text{coronal}} = 0.139$ ($P = 0.444$) and $\tau_{\text{apical}} = -0.080$ ($P = 0.658$). The scatter plot (Fig. 1) illustrates graphically the weak correlation. The dots representing each individual sample did not show any correlation.

Discussion

In vitro, the dislocation resistance and sealing ability of filling materials have been extensively evaluated (Lucena *et al.* 2013, Pane *et al.* 2013). However, little interest has been shown in investigating a relationship between both outcomes.

In the present study, a root filling material with adhesive properties was investigated by means of the fluid transport and the push-out tests and no correlation could be established between them, meaning that the sealing ability of the tested material along the whole root canal was independent of its dislocation resistance at specific levels. The null hypothesis was therefore rejected.

Methacrylate-based sealers are designed to have adhesive properties. However, the polymerization shrinkage occurring within these materials because of the relatively high configuration factor inside root canals may provoke their detachment from dentine or from the obturation cone (Gesi *et al.* 2005). The low concentration of dimethacrylates and the absence of free radicals within the RealSeal cone could also account for its weak bond with the sealer. Furthermore, the weak adhesion reported between the sealer and dentine could be increased by stress concentrators corresponding to locations with geometric discontinuity within the material (Gesi *et al.* 2005). This could affect the dislocation resistance of

Figure 1 Scatter plot showing the weak correlation between fluid transport and dislocation resistance values.

the material and lead to the creation of pores within or along the material. Whether these pores would affect the through-and-through seal is unclear (Shanahan & Duncan 2011). In the context of the present study, the number of canals with through-and-through pores was limited. Furthermore, even though through-and-through pores will affect the fluid transport rate, it is not clear how their presence within the filling material may affect dislocation resistance (Chen *et al.* 2013).

The use of a low surface tension in the fluid transport model increases its sensitivity (Özok *et al.* 2013). This will, however, not overcome the inherent limitations of the model. Most endodontic leakage models, such as the fluid transport, glucose, bacterial penetration and capillary flow porometry, can only detect through-and-through pores (De Bruyne *et al.* 2005a,b). These are continuous from one extremity of the root canal to the other one. Any other type of void would result in a 'no leakage' reading independently of the overall root canal filling quality. The fluid transport model has therefore a tendency to overestimate the sealing quality of root fillings. Pores with a minimal diameter below the detection limit will also fail to be detected and will result in a zero reading. This is commonly described as the *floor effect* (Russo 2003). A floor effect occurs when measurements are at or close to the lower detection limit of a method. It cannot be known whether the zero readings correspond to the absence of through-and-through pores or to through-and-through pores with a diameter below the detection limit. This potential loss of data could have influenced the correlation coefficient determination in this study. A potential way to overcome this limitation would be to test shorter root sections.

The push-out test gives the dislocation resistance of a material. The forces that resist dislocation are the bond strength of the material to the surrounding substrate and frictional forces. The push-out test provides therefore relevant information on the adhesion ability of a material to the surrounding dentine (Goracci *et al.* 2005). It is, however, influenced by experimental factors (Carneiro *et al.* 2012) and the material properties (Chen *et al.* 2013, Pane *et al.* 2013). In the present study, the relationship between fluid transport and push-out tests was investigated at both coronal and apical root levels and no correlation was found. Importantly, the correlation coefficients were calculated for a single experimental group, separately for each root level.

The findings of the present study are in contradiction to those of Neelakantan *et al.* (2011), who found a high negative correlation between dislocation resistance and fluid transport. Differences in methodology, such as the type of sealer and its mode of placement, the appropriate use of control groups and the fluid transport testing fluid, may account for the difference in findings between both studies. Also, the correlation coefficient reported in that study may have been biased because of the lack of homogeneity in the sample. The effects of the experimental intervention on both outcome variables in the different groups may have generated data clustering, leading to a spurious high correlation (absolute value). Such high coefficient may in fact have been caused by the arrangement of the groups rather than by the true relationship between both outcome variables. This type of bias has been previously described by De-Deus *et al.* (2012), who mentioned the risk of generating noise in correlation analysis when using more than one experimental group.

Even though the fluid transport model is considered as nondestructive, it is known from previous leakage studies that the root canal seal could be modified over time. This phenomenon is generally attributed to water sorption (Santos *et al.* 2010). It is not clear whether water sorption takes place because of the moisture left within the root canal after filling or because of the liquid compressed within the root canal filling pores during fluid transport testing. The use of a control group for the push-out test in the present study can therefore be considered as an attempt to control that the fluid transport did not significantly alter the dislocation resistance of the filling material.

Whilst the fluid transport and push-out tests may provide pertinent information, respectively, about the sealing ability and dislocation resistance of root canal filling materials, the fact that no relationship could be demonstrated between both methods does not *per se* mean that no relationship exists between adhesion and sealing ability, but only that the results of these two methods do not correlate. Future studies should aim to assess whether such correlation could be detected with other materials as well as on shorter root sections.

Conclusion

The present study could not detect any relationship between the sealing ability and dislocation resistance

of a methacrylate-based root canal filling. Under the conditions of the present study, the sealing ability of the tested material was independent of its adhesive properties as indicated by its dislocation resistance.

References

- Bishop D, Griggs J, He J (2008) Effect of dynamic loading on the integrity of the interface between root canal and obturation materials. *Journal of Endodontics* **34**, 470–3.
- Carneiro SM, Sousa-Neto MD, Rached FA Jr, Miranda CE, Silva SR, Silva-Sousa YT (2012) Push-out strength of root fillings with or without thermomechanical compaction. *International Endodontic Journal* **45**, 821–8.
- Chen WP, Chen YY, Huang SH, Lin CP (2013) Limitations of push-out test in bond strength measurement. *Journal of Endodontics* **39**, 283–7.
- De Bruyne MA, De Bruyne RJ, Rosiers L, De Moor RJ (2005a) Longitudinal study on microleakage of three root-end filling materials by the fluid transport method and by capillary flow porometry. *International Endodontic Journal* **38**, 129–36.
- De Bruyne MA, Verhelst PC, De Moor RJ (2005b) Critical analysis of leakage studies in endodontics. *Revue Belge de Médecine Dentaire* **60**, 92–106.
- De-Deus G, Murad C, Paciornik S, Reis CM, Coutinho-Filho T (2008) The effect of the canal-filled area on the bacterial leakage of oval-shaped canals. *International Endodontic Journal* **41**, 183–90.
- De-Deus G, Brandão MC, Leaf F *et al.* (2012) Lack of correlation between sealer penetration into dentinal tubules and sealability in nonbonded root fillings. *International Endodontic Journal* **45**, 642–51.
- Faul F, Erdfelder E, Buchner A, Lang AG (2009) Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behavior Research Methods* **41**, 1149–60.
- Fortin D, Swift EJ Jr, Denehy GE, Reinhardt JW (1994) Bond strength and microleakage of current dentin adhesives. *Dental Materials* **10**, 253–8.
- Gesi A, Raffaelli O, Goracci C, Pashley DH, Tay FR, Ferrari M (2005) Interfacial strength of resilon and Gutta-Percha to intraradicular dentin. *Journal of Endodontics* **31**, 809–13.
- Goracci C, Fabianelli A, Sadek FT, Papacchini F, Tay FR, Ferrari M (2005) The contribution of friction to the dislocation resistance of bonded fiber posts. *Journal of Endodontics* **31**, 608–12.
- Laplace PS (1805) *Traité de Mécanique Céleste. Supplément au dixième livre du Traité de Mécanique Céleste*, vol. **4**. Paris, France: JBM Duprat, pp. 1–79.
- Lucena C, Lopez JM, Pulgar R, Abalos C, Valderrama MJ (2013) Potential errors and misuse of statistics in studies on leakage in endodontics. *International Endodontic Journal* **46**, 323–31.
- Nagas E, Uyanik O, Durmaz V, Cehreli ZC (2011) Effect of plunger diameter on the push-out bond values of different root filling materials. *International Endodontic Journal* **44**, 950–5.
- Neelakantan P, Subbarao C, Subbarao CV, De-Deus G, Zehnder M (2011) The impact of root dentine conditioning on sealing ability and push-out bond strength of an epoxy resin root canal sealer. *International Endodontic Journal* **44**, 491–8.
- Neme AL, Evans DB, Maxson BB (2000) Evaluation of dental adhesive systems with amalgam and resin composite restorations: comparison of microleakage and bond strength results. *Operative Dentistry* **25**, 512–9.
- Özok AR, Verhaagen B, Wesslink PR (2013) Improving the accuracy of a fluid transport method. *International Endodontic Journal* **46**, 348–54.
- Pane ES, Palamara JE, Messer HHJ (2013) Critical evaluation of the push-out test for root canal filling materials. *Journal of Endodontics* **39**, 669–73.
- Russo R (2003) *Statistics for the Behavioural Sciences: an Introduction*. East Sussex, UK: Psychology Press, pp. 162–4.
- Santos J, Tjaderhane L, Ferraz C *et al.* (2010) Long-term sealing ability of resin-based canal filling. *International Endodontic Journal* **43**, 455–60.
- Shanahan DJ, Duncan HF (2011) Root canal filling using Resilon: a review. *British Dental Journal* **211**, 81–8.
- Shemesh H, van den Bos M, Wu MK, Wesslink PR (2007) Glucose penetration and fluid transport through coronal root structure and filled root canals. *International Endodontic Journal* **40**, 866–72.
- Van Noort R (2013) Principles of adhesion. In: Van Noort R, ed. *Introduction to Dental Materials* 4th edn. Mosby: Elsevier, pp. 51.
- Young T (1805) An essay on the cohesion of fluids. *Philosophical Transactions of the Royal Society of London* **95**, 65–87.