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Letter to the Editor

Considerations about the use of the “push-out” test in Endodontic research

Dear Editor,

In 2008, a letter entitled ‘New directions in old leakage models...’ (De-Deus 2008) was published in the *International Endodontic Journal* (IEJ). The author stressed the necessity of establishing the ‘clinical significance of endodontic leakage models’ rather than ‘undertaking the simple comparisons of the sealing ability of endodontic materials or techniques’. The author questioned the validity of using leakage models outcomes as surrogate markers for endodontic outcome.

Few years later, in 2012, the IEJ published an editorial entitled ‘Research that matters – root canal filling and leakage studies’ (De-Deus 2012). This editorial provided ‘guidelines’ for potential contributors of the journal about the type of studies it considered to be relevant regarding leakage and root canal filling more broadly. The author asserted that ‘many laboratory leakage models are poorly designed with confounding factors that are not controlled for’ and it encouraged ‘investigators to consider methodological issues that can contribute to our knowledge base’. Leakage studies with comparative purposes were no longer accepted by the IEJ.

In the last few years, the adhesive properties of endodontic filling materials have gained attention from the endodontic research community, as seen by the number of publications in the field. A PubMed search conducted on 11 November 2014 with the terms “push-out” AND “root filling” NOT “post” for the period between 1 January 2000 and 31 December 2009 resulted in 23 papers, whereas the same search for the last 5 years generated only 51 papers. Comparative adhesion tests are widely used to rank root filling materials and techniques (Marending *et al.* 2013, Scelza *et al.* 2014, Topçuoğlu *et al.* 2014). Hence, adhesive properties seem to be considered by some as a potential surrogate marker for endodontic outcome, despite the absence of evidence regarding the clinical significance of adhesion tests for root canal fillings. Amongst the different models designed to evaluate adhesive properties, the push-out test represents an interesting tool to investigate the

interfacial shear behaviour of materials adhering to root canal dentine. The application of a load onto a set material provides information on dislocation resistance and interface failure behaviour. Because this method is commonly used in endodontic research, and in an effort to prevent history from repeating itself, we would like to take this opportunity to acknowledge some critical parameters that could lead to methodological issues.

Friction

Frictional sliding contributes largely to the dislocation resistance, and whether the push-out test measures the ‘bond strength’ can therefore be questioned (Goracci *et al.* 2005). This frictional component is influenced by the properties of materials as well as by the dentine surface characteristics such as its micro-architecture and rugosity.

Due to the Poisson effect, when a material is compressed in one direction, it has a tendency to expand in the two perpendicular directions (Lakes 1993). Poisson’s expansion increases the contact pressure, necessitating an increased load to overcome friction (Chandra & Ghonem 2001). The amount of expansion for a given material will be determined by its elasticity modulus (Mott & Roland 2009). Materials with different elastic moduli will therefore undergo different amounts of frictional shear and any attempt to compare their true adhesion abilities by the push-out method could consequently be biased (Chen *et al.* 2013, Pane *et al.* 2013). In published studies, calculating and displaying the elastic moduli of the tested materials when comparing their dislocation resistance could therefore provide valuable additional information to the reader, even though ideally, only materials with similar elastic moduli should be compared, if the researchers are attempting to compare true adhesion ability.

Also, the geometry of the test cavity such as the degree of divergence of the canal wall in the direction of the applied load plays a role (Chandra & Ghonem 2001). A push-out test conducted in a cavity with parallel walls will express a dislocation resistance mainly revealing friction rather than true shear stress because of the Poisson effect. On the other hand,

performing the testing in a cavity with its geometry diverging in the forward direction of the applied load will reveal more about the tensile component of the force, by reducing the influence of frictional sliding.

Configuration factor (C-factor)

The C-factor is defined as the ratio of the bonded surfaces of a restoration to the unbonded ones (Feilzer *et al.* 1987). The root canal could be regarded as a Class I cavity with an extremely high C-factor because of its elongated geometry (Tay *et al.* 2005). The composition and polymerization pattern of a material, as well as the geometry of the cavity in which it polymerizes, could influence the polymerization stress the material undergoes. For materials such as methacrylate resin-based sealers that are subject to high polymerization stress when setting in high C-factor cavities, this could result in adhesive detachment that will affect their dislocation resistance (Bergmans *et al.* 2005, Tay *et al.* 2005, Bouillaguet *et al.* 2007). On the other hand, other materials are relatively impervious to the effect of cavity configuration (Bergmans *et al.* 2005). For the sake of illustration, if we consider an instrumented root canal of 10 mm height to be a perfect frustum of dimensions 40.10^{-2} mm at its tip with a taper of 6%, then its calculated C-factor has a value of 24.18. In comparison, the calculated C-factor of a 1 mm-thick cavity obtained from a section between 7 and 8 mm away from the tip in the same root has a C-factor value of 2.34. This significant difference will result in various outcomes in terms of polymerization stress, depending on the material. One of the main advantages of the currently used push-out model for the evaluation of root filling materials is that it permits the polymerization of sealers to occur in geometries corresponding to those encountered clinically. Therefore, the use of artificial cavities created in thin slices should, in our opinion, be avoided if possible, as the findings cannot always be extrapolated to what occurs inside an entire root canal.

Dentine characteristics

Dentine is a highly variable and inhomogeneous substrate (Arola *et al.* 2012), and its characteristics and location influence its ability to effectively allow adhesion to its surface (Zhang *et al.* 2014). Differences in dentine type and morphology along the root canal could therefore result in differences in terms of

dislocation resistance. Furthermore, differences in dentine properties have also been reported between different regions of the same roots (Zaslansky *et al.* 2005). The preparation and use of artificial cavities in dentine from regions not corresponding to the prepared root canal region could have some advantages in terms of dimension and age standardization, but throw into question any extrapolation to the substrate of interest, which is instrumented root canal dentine. Efforts to standardize test cavities should rather be directed towards adequate specimen and sample size selection, volumetric standardization and appropriate randomization. Also, the cavity preparation method could influence the characteristics of the created smear layer (Mine *et al.* 2014). The use of endodontic instruments for a correct shaping and 'conditioning' of the cavity walls should therefore be preferred for methodological accuracy.

In summary

The push-out test is a valuable test in endodontic research. Some methodological aspects should be considered for accuracy.

- Sliding friction, rather than true bond strength, largely contributes to dislocation resistance.
- The geometry of the root canal in the thin-slice model should be diverging in the forward direction of the applied load in order to reduce the contribution of frictional sliding to the dislocation resistance.
- When testing different materials, differences in elastic modulus should be avoided or at least reported.
- Push-out specimens should be sliced after the application and setting of the material, in order for results to demonstrate a realistic influence of the C-factor.
- Preparation of artificial cavities in dentine regions other than the instrumented root canal is not recommended.
- Tested surfaces should be prepared according to procedures corresponding to endodontic protocols.

Demonstrating the clinical significance of a laboratory test is not always an easy task, and such attempts have their limitations (Wu 2008). Laboratory studies should be critically assessed from a methodological point of view, and efforts should be made to improve the current *ex vivo* models (De-Deus 2012) as these are necessary to evaluate new materials and techniques.

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