An Evaluation of Intra-orifice Sealing Materials for Coronal Microleakage in Obturated Root Canals

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Objective: *To compare three flowable composites (Esthet-X flow, Beautifil flow and Filtek Z350) with a hybrid composite (Z100), and two temporary filling materials (Cavit and IRM) as intra-orifice filling materials to prevent coronal microleakage.*
Methods: *Root canal treatments were performed on 104 extracted human single-rooted premolars. Three millimetres of coronal gutta-percha was replaced by one of the six filling materials to seal the intra-orifice. After thermocycling (5°C to 55°C) for 750 cycles and immersion in Indian dye for 5 days, the teeth were evaluated for dye penetration along canal walls. The data were analysed with the Kruskal–Wallis test and the Mann–Whitney U test.*
Results: *All of the three flowable composites sealed the intra-orifice of root canals as well as Z100, but significantly better than Cavit and IRM. There was no significant difference among the three flowable composites, or between Cavit and IRM.*
Conclusion: *Flowable composites are ideal intra-orifice seals.*
Key words: *coronal leakage, flowable composite, intra-orifice seal*

Endodontic therapy aims to eliminate infection in the root canal system and to prevent re-infection from apical and coronal directions. While both apical and coronal leakages are major causes leading to root canal treatment failure, coronal leakage is thought to be a more important factor deciding the clinical outcome[1]. Thus, the prevention of coronal leakage has been the top clinical priority.

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To prevent coronal leakage, Roghanizad and Jones first placed a coronal seal into the orifice of the root canals to replace part of the gutta-percha immediately after root canal filling[2]. They replaced 3 mm of gutta-percha with Cavit™ (3M, ESPE, Germany) resin-based temporary restorative material (TERM, Dentsply International, USA) or amalgam with cavity varnish, and found that amalgam with two coats of cavity varnish sealed significantly better than Cavit and TERM. However, amalgam causes tooth discoloration and interferes with future bonding agents. Since then, a variety of materials have been tested for intra-orifice seals, including zinc oxide preparations, glass ionomer cements and composite resins.

A couple of zinc oxide preparations were previously compared[3-5], but the results were not conclusive. For example, Cavit was shown to have better sealing ability than immediate restorative material (IRM) and Super-EBA, but wore off faster than the latter[3]. In addition, the free eugenol in IRM and Super-EBA was found to interfere with dentinal bonding agents and polymerisation of composite resins. In another study, Balto et al found no significant difference in coronal leakage between Cavit, IRM and TempBond® (Kerr Corporation, Japan) (10 parts zinc oxide and 1 part eugenol) after post space preparation[4]. However, a recent study found that two new temporary materials, Tempit Ultra-F (Centrix, Japan) and Tempit (Centrix, Japan), had less leakage than Cavit and IRM[5].

Different glass ionomer cements were also compared. Wolcott et al tested three pigmented glass ionomer cements[6]. Of those, Vitrebond™ (3M, ESPE) was found to be better than Ketac-Bond™ (3M, ESPE) or GC America (Chicago, IL, USA) and was suggested to be an ideal intra-orifice barrier. While glass ionomer cements are good intra-orifice barriers, other materials may perform better. For example, composite resins (dentine sealants and TERM) sealed more effectively than glass ionomer cements in preventing coronal leakage[7]. In recent years, composite resins have become more popular.

Among them, flowable composites have stood out as ideal intra-orifice sealing materials due to their superior advantages. They have high flowability, ability to form layers of minimum thickness, high flexibility, radiopaqueness and are available in different colours[8]. During the preparation of the present study, two other *in vitro* studies examined microleakage of flowable composites as intra-orifice sealing materials, but found inconsistent and inconclusive results[9,10]. Jenkins et al found the flowable composite Teric sealed better than Cavit and ProRoot™ MTA (Dentsply International)[9], whereas Sauaia et al found the flowable composite Flow-it exhibited more leakage than Cavit and Vitremer (3M, ESPE) (a glass ionomer cement)[10]. Therefore, it is necessary to further study the sealing ability of flowable composites as intra-orifice barriers.

The present study aimed to evaluate and compare three flowable composites (Esthet-X flow [Dentsply, USA], Beautifil flow [Shofu, Kyoto, Japan] and Filtek Z350 [3M, ESPE]), a hybrid composite (Z100), and two temporary materials (Cavit and IRM) as intra-orifice filling materials for the prevention of coronal leakage in the absence of coronal restoration.

Materials and Methods

A total of 104 single-rooted premolars extracted for orthodontic reasons were used in the present study. All teeth were examined clinically under a surgical operating microscope. Teeth with cracks, root resorption, open foramen, and calcified and curved canals were excluded. The external surfaces of the roots were cleaned with curettes to remove any debris and/or calculus, with attention not to damage the root surface.

All teeth were treated by the same clinician to reduce variability. The crowns were removed at the cemento-enamel junction (CEJ) using a carbide bur (Dentsply, Maillefer Instruments Holding Sarl, Swiss) in a high-speed handpiece with an air/water spray. The instrumentation technique used for cleaning and shaping was performed as follows: working length was established by placing a #10 K file (Dentsply Maillefer, Ballaigues, Switzerland) into the canal until visible at the apical foramen and subtracting 1 mm. A ProTaper® (Dentsply Maillefer, Ballaigues, Switzerland) Sx file was used to flare the orifice. ProTaper S1, S2, F1, F2 and F3 files were used sequentially according to the manufacturer's instructions in a crown-down technique. A total of 5 ml of 5.25% sodium hypochlorite (NaOCl) was used to irrigate the canals between each file. Once the final apical size was reached, the smear layer was removed by using 5 ml of 17% ethylenediaminetetraacetic acid (EDTA) followed by 5 ml of 5.25% NaOCl and 5 ml of distilled water[10]. All canals were dried with paper points (Gapadent, Tianjin, P.R. China).

All roots were obturated with 0.06 greater taper gutta-percha (Meta Biomed, Cheongju, Korea) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) by using the continuous wave of condensation technique (E&Q system, Meta Biomed)[5]. The plugger (Dentsply Maillefer) was used compact the gutta-percha. The gutta-percha was seared off 3 mm apical to the orifice, leaving the space for experimental materials. Excess root canal sealer was removed with alcohol-wet cotton pellets. The root filling technique was conducted while the teeth were maintained in moist saline-soaked gauze. Complete obturation of all canals was confirmed with radiographs taken in buccal-lingual and mesial-distal directions. All teeth were placed in 100% humidity at 37°C for 48 hours to allow the root canal sealer to set.

The teeth were randomly divided into six experimental groups of 14 teeth using different orifice sealing materials as follows: group 1, Esthet-X flow; group 2, Beautifil flow F02; group 3, Filtek Z350 flowable restorative; group 4, Z100 restorative; group 5, Cavit G; group 6, IRM (Table 1). The remaining 20 teeth were divided equally to positive (root-treated canals without intra-orifice sealing) and negative control (intact teeth) groups.

The coronal root canal spaces were dried, and the restorative materials were placed following the manufacturers' instructions.

The materials were inserted and adapted in the prepared 3-mm deep cavity over the root canal filling; excess material was removed. In brief, the specimens of groups 1, 2, 3 and 4 were etched with 37% phosphoric acid (H_3PO_4), washed and then gently dried with air spray.

Table 1 Materials used in the study

Materials	Manufacturer	Type	Shade	Bonding system
Esthet-X® flow	Dentsply/Caulk Milford, DE, USA	Liquid micro hybrid	A3	Prime & Bond® NT™ (full-acid)
Beautifil® flow F02 (low flow)	Shofu, Kyoto, Japan	Fluoride releasing flowable restorative	–	FL-Bond II (self-acid)
Filtek™ Z350 flowable restorative	3M ESPE, St Paul, MN, USA	Nano-filled restorative	A2	Adper™ Single Bond Plus (self-acid)
Z100™ restorative	3M ESPE, St Paul, MN, USA	Hybrid resin composite	A3	Adper™ Single Bond Plus (self-acid)
Cavit™ G	3M ESPE, Seefeld, Germany	Temporary filling material	–	–
IRM®	Dentsply/Caulk Milford, DE, USA	Intermediate restorative	–	–

Table 2 Mean dye penetration measurements (mm)

Material	Number of teeth	Mean dye penetration	SD	Range
Esthet-X® flow	14	0.58	0.45	0–1.1
Beautifil® flow	13	0.66	0.51	0–1.5
Filtek™ Z350	14	0.81	0.68	0–2.2
Z100™	14	0.93	1.39	0–4.1
Cavit™ G	14	1.52	0.95	0.6–4.3
IRM®	13	2.01	1.39	0.7–4.4
Positive	10	3.66	1.32	1.7–5.4
Negative	10	0.00	0.00	0

Bonding systems (Table 1) were applied to the dentine using a saturated disposable brush. The excess was removed by a quick air spray and then cured with a visible light activator (Dentsply DeTrey). The composites were injected or inserted into the cavity in two layers and each layer was cured with a visible light activator for 40 s. In groups 5 and 6, Cavit G or IRM was placed into the prepared root canal cavity over the gutta-percha and then condensed individually with the plugger. The excess was removed with a moistened sterilised cotton pellet.

All of the experimental teeth and positive control group received three layers of nail polish, leaving only the area of the canal's orifice exposed to provide uniform control of any lateral or accessory canals. All surfaces of the negative control group were completely sealed with three layers of nail polish.

The specimens were subjected to thermocycling between 5°C and 55°C for 750 cycles. The dwell times in each bath and the time intervals at room temperature between baths were 1 minute[10]. Subsequently, the teeth were immersed in Indian ink for 5 days. Following exposure to the dye, the teeth were rinsed in tap water and the nail polish was completely removed with a scalpel. Then the teeth were decalcified in 5% hydrochloric acid (HCl) for 3 days with constant stirring followed by a running water wash. The teeth were dehydrated for 3 hours in each of 50%, 75% and 95% ethyl alcohol and 2 hours in 100% ethyl alcohol, and then cleared by immersion into methyl salicylate. Two specimens were lost during rinsing procedures, thus group 4 (Beautifil flow) and group 6 (IRM) had 13 specimens each.

The experimental materials were observed over 360 degrees and leakage was observed by a calibrated examiner using a ×10 stereomicroscope (Carl Zeiss Vision, München-Hallbergmoos, Germany). The leakage was measured to the greatest penetration from the coronal extent of the orifice material to the nearest 0.1 mm.

Kruskal–Wallis analysis was performed to identify whether or not there was at least one statistically significant difference among the groups, and a Mann–Whitney *U* test was performed to determine which group was different from the others with the SPSS statistical program version 10.0 (SPSS, Chicago, IL, USA). The level of significance was set at $P < 0.05$.

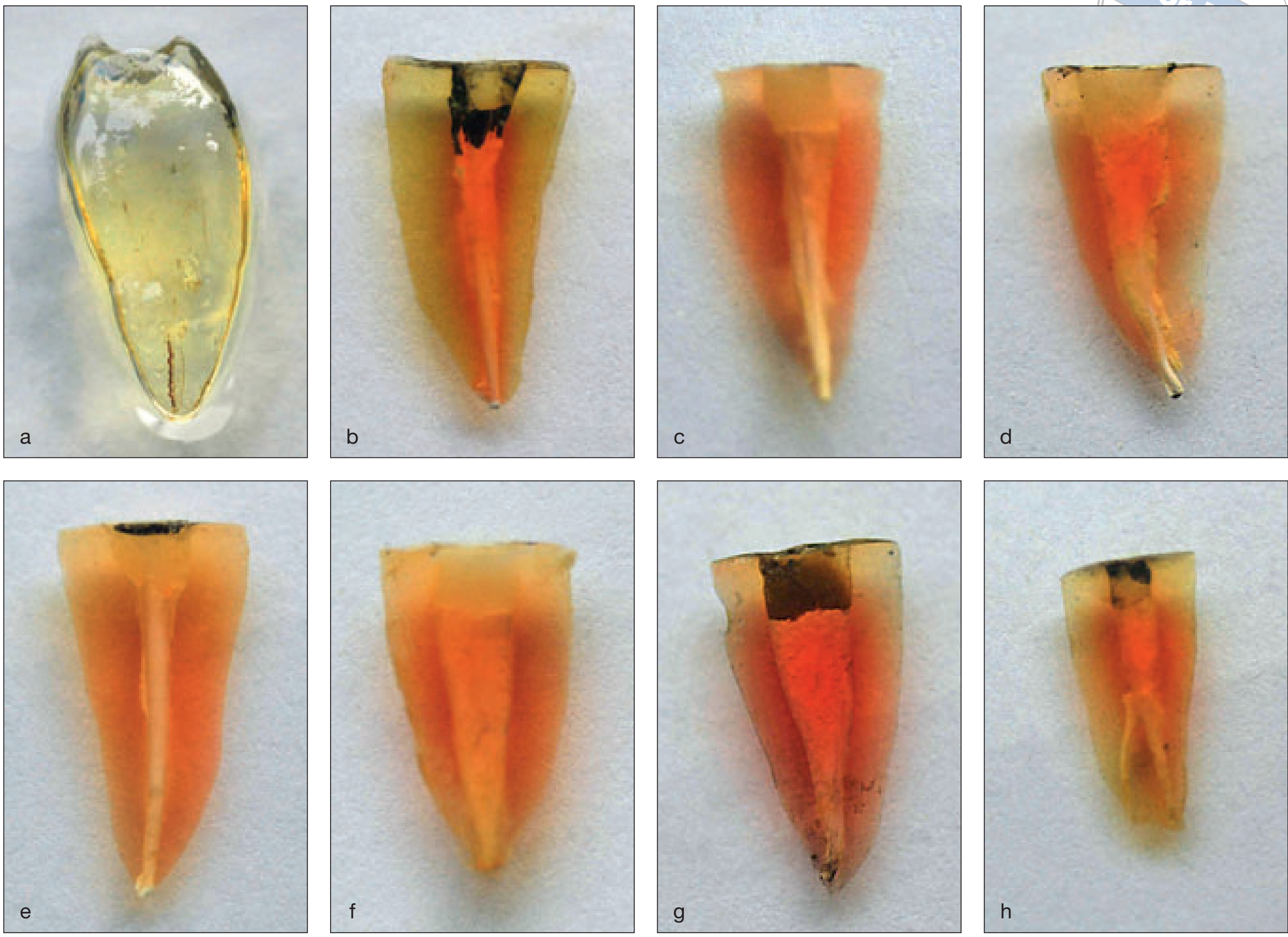

Fig 1 One representative specimen from each group: dye penetration from coronal area and throughout the root along canal walls. a: Negative group, b: Positive group, c: Esthet-X flow group, d: Beautifil flow group, e: Filtek Z350 group, f: Z100 group, g: Cavit group, h: IRM group.

Results

The mean dye penetration measurements and their standard deviations are presented in Table 2. All negative control teeth showed no dye penetration, whereas all positive control teeth demonstrated extensive dye penetration. The specimens from the three flowable composite groups all showed the leakage at less than 3 mm, while the specimens from the other three experimental groups showed the maximum leakage at more than 4 mm. However, the mean dye penetration of Z100 (0.93 mm) was much less than Cavit G (1.52 mm) and

Table 3 Statistical analysis.

Materials	Esthet-X® flow	Beautifil® flow	Filtek™ Z350	Z100™	Cavit™ G	IRM®
Esthet-X® flow	–	$P < 0.679$	$P < 0.662$	$P < 0.657$	$P < 0.003$**	$P < 0.003$**
Beautifil® flow	–	–	$P < 0.808$	$P < 0.521$	$P < 0.008$**	$P < 0.009$**
Filtek™ Z350	–	–	–	$P < 0.457$	$P < 0.01$**	$P < 0.01$**
Z100™	–	–	–	–	$P < 0.021$*	$P < 0.02$*
Cavit™ G	–	–	–	–	–	$P < 0.645$
IRM®	–	–	–	–	–	–

*Statistically significant difference ($P < 0.05$); **Statistically significant difference ($P < 0.01$).

IRM (2.01 mm). The dye penetration from the coronal area and throughout the root along the canal walls of only one representative specimen from each group is presented in Fig 1.

The statistical analysis results are presented in Table 3. Compared with Cavit G and IRM, the three flowable composites showed significantly less leakage ($P < 0.01$). Similarly, the hybrid composite Z100 had significantly less leakage than Cavit G and IRM ($P < 0.05$). There were no statistically significant differences among the three flowable composite groups. Furthermore, no statistically significant difference in leakage was found between the three flowable composites and hybrid composite Z100, or between Cavit G and IRM.

Discussion

Application of an intra-orifice seal to prevent coronal leakage has been widely accepted[11]. The criteria for an ideal intra-orifice seal were proposed as follows: (i) easily placed; (ii) bonds to tooth structure; (iii) seals effectively against coronal microleakage; (iv) easily distinguished from the natural tooth structure and (v) does not interfere with the final restoration of the access preparation[6,11].

Of the criteria, sealing against coronal microleakage and bonding to tooth structure are the most important. The present results demonstrated that flowable composites sealed as well as hybrid composite Z100 and confirmed the previous findings showing that flowable composites provided as good a seal as hybrid composites to prevent microleakage[12]. The authors also demonstrated that the specimens in the Z100 group, but not the three flowable composite groups, had dye penetration into gutta-percha. This suggests that flowable composites have better adaptation to the cavity walls than the hybrid composites. Composites' adaptation to cavity walls depends on the 'resin tag'. Cavit G relies on mechanical retention and its expansion property in contact with moisture, whereas IRM only depends on mechanical retention. Moreover, flowable composites have the ability to form a layered structure of minimum thickness to improve or eliminate air inclusion or entrapment[8]. Consequently, our results showed that flowable composites and hybrid composite Z100 had significantly less leakage compared with Cavit G and IRM, which is consistent with the findings of Jenkins et al[9]. However, Sauaia et al[10] had an observation opposite to the authors' results. They found that Flow-it demonstrated more leakage than Cavit G. This discrepancy might be due to the different sealers used. While Sauaia et al[10] used eugenol-containing sealant, Jenkins et al[9] and the present study used resin formulation sealer. Released eugenol can penetrate dentine, change tooth structure and reduce shear bond strengths of composite[13-15]. In addition, the present results indicated that there was no significant leakage difference between Cavit G and IRM, which was difficult to compare with previous studies, since previous findings are conflicting[5,16-20].

Another very important criterion is that an ideal intra-orifice seal does not interfere with the final restoration of the access preparation[11]. Most patients prefer tooth-coloured composite restorations. Thus, the material beneath composites should have no negative influence on composites. Flowable composites have been recommended as liners beneath composites due to their low viscosity, increased elasticity, and wettability, which helps relieve stresses during polymerisation shrinkage of the restorative resin[21-24]. However, IRM is not recommended for use as a base under resin restoratives because eugenol may interfere with the polymerisation of composites[25].

Easy application is also an important consideration since the coronal 3 mm of the canal is a very small cavity and the materials need to be placed within canals. Adding to the advantages of high flowability, the excellent ability to penetrate into irregular spaces allows flowable resin composites to be used in situations where access is restricted or good penetration is required[8,26]. The flowable resin composites are ideal for these situations because they are easily syringed into the cavities.

The flowable composites also meet the other criteria stated above. They can be easily distinguished from the natural tooth structure by choosing a shade in contrast to dentine. Another possible solution is to add pigment into flowable composites if necessary[6].

In conclusion, the present study found that the flowable composites Esthet-X flow, Beautifil flow, and Filtek Z350 sealed the intra-orifice of root canals as well as hybrid composite Z100 and better than Cavit G and IRM. The results suggest that flowable composites can serve as ideal intra-orifice seals. Further *in vivo* studies and long-term evaluation are warranted.

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