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An *In Vitro* Comparative SEM Study Of Marginal Adaptation Of IRM, Light- And Chemically-Cured Glass Ionomer, And Amalgam In Furcation Perforations

Abstract

The furcation regions of 30 human mandibular molars were perforated and sealed using four different materials: IRM, light- and chemically-cured glass ionomer cement (GIC), and amalgam. The materials were compared for marginal gaps in coronal, mid, and apical regions after routine SEM processing. While light-cured GIC showed the smallest gaps in the three regions, in mid and coronal regions chemically-cured GIC, and in apical regions amalgam, showed the largest gaps. IRM cases showed the highest rate of fillings with a good "fit", whereas the majority of amalgam cases and none of the chemically-cured GIC cases were overfilled.

Introduction

Perforation of the furcation region is an artificial communication between the root canal system and the periodontal ligament (PDL) through the floor of the pulp chamber (1). Perforations can result from a resorptive process or can be of iatrogenic origin (2). The trauma of a perforation and the subsequent inflammation may rapidly produce a communication with the gingival sulcus and an irreversible periodontal lesion. Even when these defects are sealed off immediately, epithelial proliferation and pocket formation may still occur (2), which creates the most serious obstacle to healing (3). The defect is usually surgically inaccessible especially if the perforation is lingually located in a mandibular molar or in the trifurcation of a maxillary molar. The surgical approach will often lead to chronic pocket formation (4).

Perforations have been sealed using different materials with varying degrees of success such as: zinc phosphate cement, glass ionomer cement, indium foil and amalgam, cavit, gutta-percha, calcium hydroxide, tricalcium phosphate, teflon discs, dentine chips, ZOE, hydroxyapatite (5), AH26 (6), mineral trioxide aggregate (MTA) (7) and Super EBA (8).

The prognosis of a perforation depends on: its location and size; the time elapsed before the defect is repaired; the sealability (9), the solubility (10) and biocompatibility of the material (5); distance from the sulcular epithelium; amount of PDL irritation (5); and accessibility to the main canal (2). Furthermore, contamination of the material with haemorrhage should be avoided. Clinical experience indicates that larger perforations do not respond as well to repair as do smaller ones (11). Lemon (11) noted that the size of a perforation is relative to the size of the tooth, and a larger tooth responds more favourably to repair.

A major difficulty with non-surgical repair is the extrusion of the filling material into the PDL, which interferes with periodontal reattachment. As early as 1901, Guilford suggested that pulp chamber floor perforations could be repaired with moistened plaster of Paris fixed in place with a zinc phosphate cement (9). Lemon (11) developed the "internal matrix concept" where an intermediate layer of a material is placed to form a barrier prior to placement of the repair material. Materials such as tricalcium phosphate, teflon discs, indium foil, hydroxyapatite, dentine chips, decalcified freeze-dried bone, calcium sulphate, calcium hydroxide (1), and bovine collagen (8) have been used as a matrix.

The purpose of this study was to measure the gaps around four materials used to repair furcation perforations in human teeth *in vitro*.

Materials And Methods

Thirty human mandibular molars with widely separated roots were selected. Teeth were cleaned of blood and soft tissues by placing them in a 5.25% solution of sodium hypochlorite for 30 minutes. They were then washed with tap water and stored in normal saline until used.

After access cavities had been prepared, the pulp chamber floors were perforated using a No. 2 high-speed round bur. Diameters of the perforations were standardised but the depth could be variable depending on the dentine-cementum thickness.

To provide a simulated oral environment, moistened cotton pellets were placed in the furcations and the perforations were sealed with the following:

Group A: Ten IRM samples (Type III, Class I, Caulk Div., Dentsply)

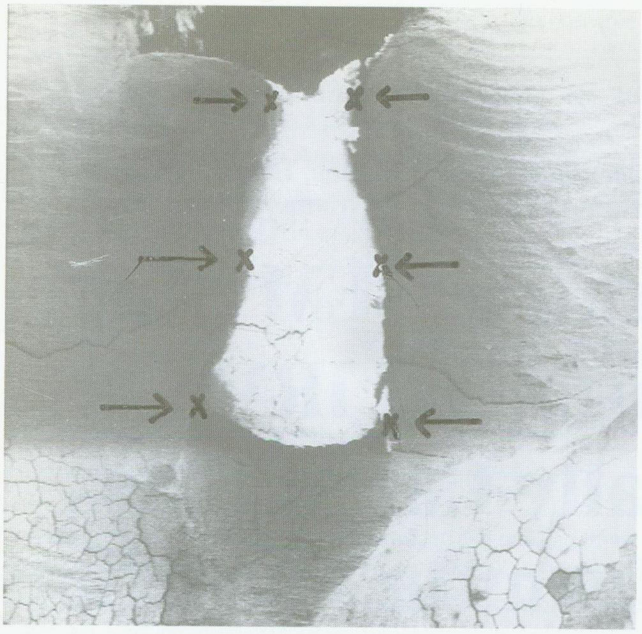

Figure 1: SEM photograph of a sample filled with chemically-cured GIC (x20). Vertical "fit" is demonstrated and the arrows indicate the six measurement points.

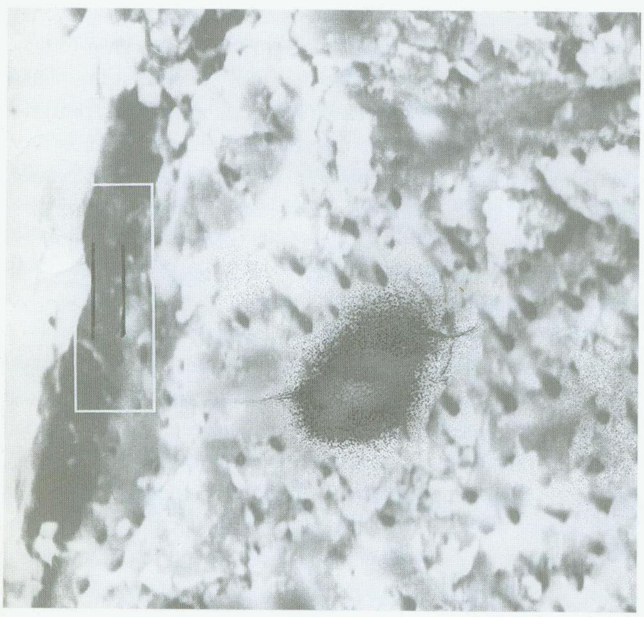

Figure 2: A gap in the middle region of a light-cured GIC filling (x1000). Dentinal tubules are evident on the left.

Group B: Five light-cured GIC (G.C. Fuji II restorative)
Group C: Five chemically-cured GIC (Opusfil restorative cement, Davis Schottlander)
Group D: Ten amalgam (non-$\gamma 2$, Sina, Faghihi Lab).

IRM and chemically-cured GIC were placed into perforations with the tip of an explorer and condensed with the end of a paper point. Light-cured GIC was placed with the tip of an explorer and allowed to flow apically, and then cured. Amalgams were placed into the perforation with an amalgam carrier and condensed with an amalgam plugger larger than the perforation.

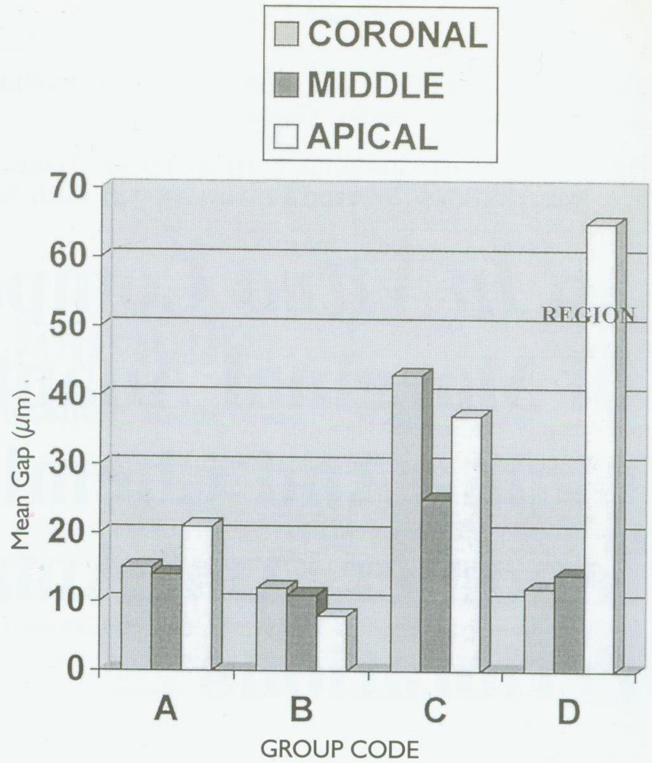

Figure 3: Graph of mean gap (in microns) of each material according to the three regions. (A – IRM; B – light-cured GIC; C – chemically-cured GIC; D – amalgam).

The access cavities were then filled using cotton pellets and cavit (ESPE) and the teeth wrapped in aluminium foil for 24 hours for final setting, except for the amalgam group, in which the buccolingual sectioning with a diamond disc was performed after one week. Routine SEM processing was performed according to the method of Torabinejad et al. (13) and the samples were then examined (Zeiss, DSM, 940A).

The gaps between the filling and perforation walls were measured in microns at six points on the left and right sides (apical, mid and coronal) with 1000x maginification. The filling materials were also assessed for quality of filling using 20x magnification (Figs. 1 & 2). The categories were: "over-filled", "fit-filled" and "under-filled". Finally, the six measurements from the left and right points of each material were calculated as the region's mean gap.

Results

Maximum and minimum gap measurements of each group are listed in Table 1 according to the three regions. The total mean gaps for each group were also calculated (Table 2, Figs. 3–5). The

Table 1: Gap measurements for each group (μm)

Group	Regions / Materials	Coronal		Middle		Apical	
		Max	Min	Max	Min	Max	Min
A	IRM	26.31	5.47	41.72	4.82	69.01	5.47
B	Light-Cured GIC	18.26	8.29	20.98	3.72	15.98	0.00
C	Chemically-Cured GIC	95.74	24.74	48.75	5.18	86.32	6.27
D	Amalgam	26.72	2.80	30.10	5.92	371.84	4.92

Table 2: Total mean gaps for each group (μm)

Group	Materials \ Regions	$\bar{x}$ Coronal	$\bar{x}$ Middle	$\bar{x}$ Apical
A	IRM	14.82	13.99	20.58
B	Light-Cured GIC	12.43	11.04	8.01
C	Chemically-Cured GIC	42.98	24.53	37.15
D	Amalgam	12.46	13.79	64.57

chemically-cured GIC group ($\bar{x}$ = 42.98 μm) showed a significant difference with the other groups in the coronal region (ANOVA, $P<0.05$). No significant difference was observed in the mid region (ANOVA, $P<0.05$) and in the apical region, non-parabolic analysis showed no significant difference (Kruskal-Wallis).

Comparing the total mean gaps of each group, light-cured GIC ranked the least (10.49 μm), IRM was second (16.46 μm), amalgam was third (30.27 μm) and chemically-cured GIC had the largest gaps (34.88 μm).

While the amalgam group had the most over-filled cases, a tendency for under-filling was observed with chemically-cured GIC (Fig. 6).

Discussion

Amalgam is conventionally used for repair of perforation defects. IRM is well known for its antibacterial effect, higher strength and less solubility when compared to other conventional ZOE cements. GIC is a dentine adhesive material with acceptable strength, biocompatibility and good sealing ability (12). Alhadainy and Himel (5) found GIC superior to amalgam in their dye leakage study, and this was considered to be as a result of good flow and bonding properties of GIC to dentine. Our results are in support of their findings and explanation.

Light-cured GIC showed the smallest gap measurements in all three regions compared to chemically-cured. This confirms earlier studies and may be as a result of fast setting which reduces the risk of moisture or blood contamination. Amalgam and chemically-cured GIC showed larger mean gaps than IRM, which is in support of the study by Mittal et al. (12).

In the IRM group, the largest gap was in the apical region (20.58 μm) and the smallest in the mid region (13.99 μm) (Table 2), which may be due to polymerisation shrinkage or compaction force. Both the chemical and light-cured GIC showed the largest gaps in the coronal region. The smallest gap with light-cured GIC was in the apical region (8.01 μm), which tends to confirm its flowability. The smallest gap with chemically-cured GIC was in the mid region (24.53 μm) (Table 2). In the amalgam group the largest gap was in the apical region (64.57 μm) and the smallest in the coronal region (12.46 μm).

Because the sectioning of the amalgam group was carried out only one week after the condensation, no signs of corrosion products were observed.

There are generally two methods for the SEM gap measurements – longitudinal sectioning and resin replicas. Factors which may influence measurements include the following:

- Artifacts or cracks may be created during the sectioning and preparation process.
- SEM views are two-dimensional and so the depth of the gap is not certain and it is not clear if the gap extends along the whole margin (13).

Abdal and Retief (14) and Yashimura et al. (15) evaluated the

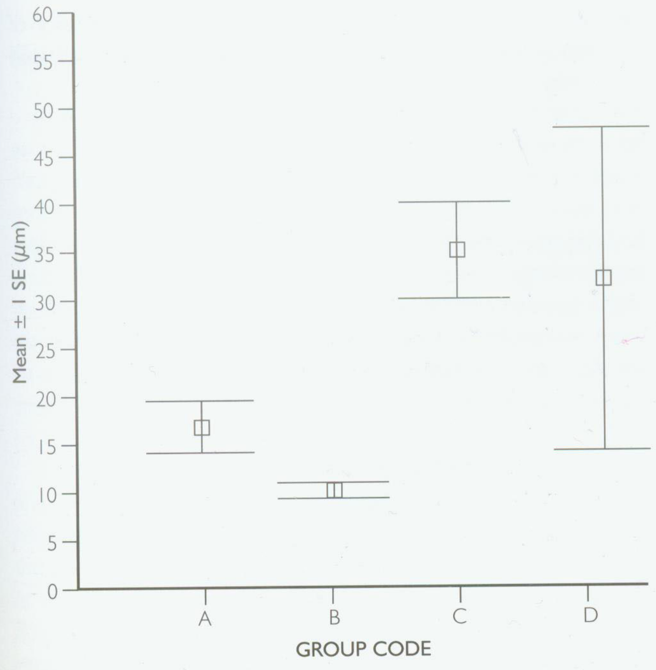

Figure 4: Mean and standard deviation (in microns) of the gap of each group according to the material. (A – IRM; B – light-cured GIC; C – chemically-cured GIC; D – amalgam).

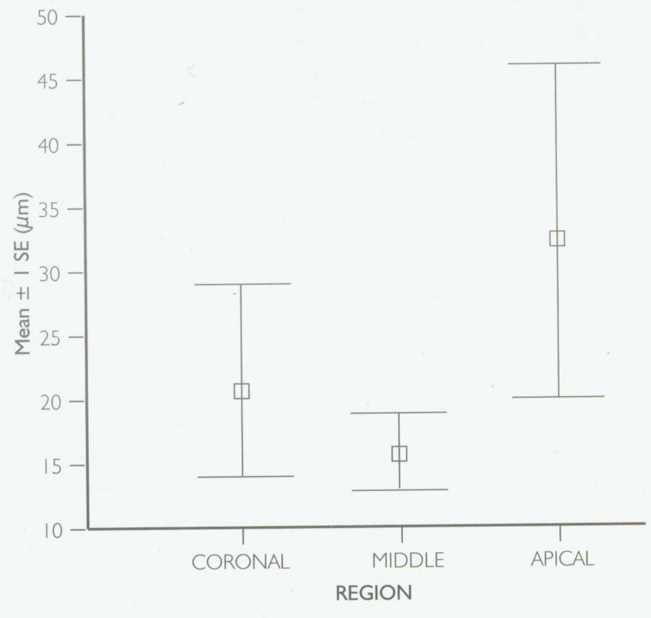

Figure 5: Mean and standard deviation (in microns) of the gap according to the region.

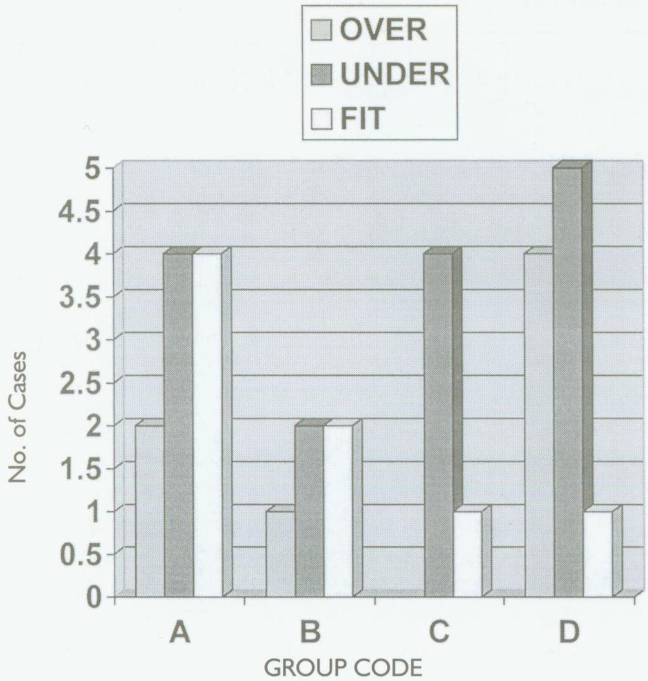

Figure 6: Bar graph of number of over-filled, "fit"-filled and under-filled cases of each material. (A – IRM; B – light-cured GIC; C – chemically-cured GIC; D – amalgam).

adaptation of retrofilling materials and found no correlation between marginal gaps and degree of leakage, but Stabholz et al. (16) could find a correlation between the gap and sealing ability of retrofillings. The present authors plan a dye leakage study of the same procedure and materials to assess the possible correlation of marginal gap and microleakage.

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