Sealing Ability of Injectable Dental Composites, Biodentine and MTA in Repairing Furcal Perforation of Permanent Molar Teeth

Yanti Johari[1,2]*, Nur Aini Pungut[1], Valerie Wong Xiu Yin[1],
Mohd Fadhli Khamis[1,2], Mohd Nazrulhuzaimi Md Yusoff[1]

1. School of Dental Sciences, Universiti Sains Malaysia, Health Campus, 16150 Kubang Kerian, Kelantan, Malaysia.
2. Hospital Universiti Sains Malaysia, Health Campus, 16150 Kubang Kerian Kelantan, Malaysia.

Abstract

Furcal perforation is one of the most common undesired complications during dental treatment. It requires immediate seal to ensure the prognosis of the involved tooth. The aim of this study is to compare the sealing ability of injectable dental composites, namely G-aenial Universal Flo (GAUF) and Paracore with Biodentine and Mineral Trioxide Aggregate (MTA) as furcal perforation materials. This study was conducted on 68 extracted teeth. Upon decoronation of the tooth 4mm above cementoenamel junction, endodontic access cavity was done followed by the creation of furcal perforation in the pulp chamber floor. The teeth were assigned randomly into four experimental and two control groups. These perforations were then repaired with the intended materials. The teeth were submerged in 2% basic fuchsin for 24 hours then sectioned and evaluated for dye leakage. The data were analysed using Median's Test and Mann Whitney U Test. One specimen for each test group were inspected under scanning electron microscope (SEM). The results showed that the percentage of dye penetrations were significantly lower in Paracore and GAUF compared to Biodentine and MTA groups (p<0.001). Paracore demonstrated less gap at material tooth interface under SEM. Both Paracore and GAUF sealed furcal perforation better than Biodentine and MTA.

Clinical article (J Int Dent Med Res 2020; 13(4): 1428-1434)

Keywords: Furcal Perforation, Repair Material, Microleakage.

Received date: 14 July 2020 **Accept date:** 19 August 2020

Introduction

Many times dental practitioners are faced with the challenge to restore pulpal floor perforations. These perforations can occur as a result of improper access openings during endodontic treatment or in any attempt to remove carious lesion or can be due to internal or external root resorption. It is not uncommon in the past to extract the involved teeth due its unpredictable result. However, recent advances in biomaterial and techniques have made the perforation of the pulpal floor areas repairable. Materials that have been used to seal pulpal perforations in the past and current include amalgam, zinc oxide-eugenol cement, glass ionomer cement (GIC), resin based materials, resin modified glass ionomer cement (RMGIC) and Mineral Trioxide Aggregate (MTA).[1-5] The outcome can be influenced by many factors namely size and location of the defect and how quickly the perforation can be sealed.[6,7]

In general, an ideal material for treating such perforation should be easy to handle, non-toxic, non- carcinogenic, bactericidal, radiopaque, and able to adequately seal the defect site. Moreover, it is preferable for the material to have the ability to induce osteogenesis and cementogenesis. However, no available materials at present fulfill the requirement of an ideal material. Recently MTA has been claimed to have many properties that meet the requirement as a perforation material. The principle components of MTA are tricalcium silicate, tricalcium aluminate, tricalcium oxide and silicate oxide. It also promotes the deposition of cementum and reduced inflammation.[8,9] Biodentine is another material claimed to have similar composition to MTA with improved physical properties and setting time. However, both are not easy material to handle with reasonably long setting time and relatively

Corresponding author:
Dr. Yanti Johari,
BDSc, Grad Dip in Clin Dent, D Clin Dent (Prosthodontics)
School of Dental Science, Universiti Sains Malaysia, Health Campus,
16150 Kubang Kerian, Kelantan, Malaysia.
E-mail: yjohari@usm.my

expensive.[10] Therefore, a search for an alternative material to adequately repair the pulpal floor perforation is essential.

Recently, dental composite resin materials have not only being used as a restorative, lining and luting materials but also as a sealing material. Bonding to tooth structure has been an advantage of resin-based materials and the use of dentin bonding agent further improved the sealing ability. Composite resins are available in the form of macrofill, microfill, hybrid, packable composites and flowable composites. While it is desirable to use composite resin in the putty-like consistency which suit most of the clinical needs, it is handy to have a less viscous composite resin when one needs to seal dental pits and fissures and restore a small cavity, tunnel or defects. In general, flowable composites are inferior in terms of strength, wear and shrinkage, but gaining its popularity mainly because of the flow characteristic, ease of handling, and better margin adaptation. Not only the use of flowable composite has gradually increased over the years, but the application has also expanded from simply a liner/base beneath a conventional composite, to restoring some selected cavities and filling up some irregularities and defects. However, further research is needed to support this usage progression to ensure the clinical success of flowable composites.

Dental composite resins are also available as light-cure, chemical-cure or dual cure. A few studies looked into light cured composite as an alternative perforation repair material due to its short curing time, good adhesion and comparable physical properties.[11-13] However, the use of light-cured composite resin has posed some difficulties due to the location of perforation deep down inside the pulp chamber near bifurcation area. The material placed might be at risk of not being cured properly. Therefore, the use of dual cured resin-based materials for such deep restorations should be considered. Dual cure composite resin offers the advantage of its effective adherence to dentinal walls and dual curing mechanism. It dispenses at a workable viscosity that enable the material to flow into the intended site hence allowing optimal adaptation to the perforation site. Studies were carried out on MTA and light-cured composite resin as a repair materials but none for their dual-cured equivalents.[13,14] Traditionally, dual cure resin composites have been used for core build-ups and restoration of endodontically treated teeth prior to crown placement. Recently the use of dual cure resin composites has expanded to cementing direct post in the post core crown cases as well as restoration of paediatric and geriatric patients. Dual cure composite is injectable into the site similar to flowable composite.

To this date, MTA has superior sealing ability and biocompatibility compared to other restorative materials as a perforation material despite its high cost and low setting time. Hence it is essential to assess the potential use of other materials for example, injectable composites as alternative pulpal floor perforation repair materials; dual cure composite namely Paracore and flowable composite namely G-aenial Universal Flo (GAUF). The aim of this in vitro study is to compare sealing ability of Paracore and GAUF in comparison to MTA and Biodentine as perforation repair materials.

Materials and methods

Sample preparation

Sixty-eight extracted, sound or minimally restored, permanent human molar teeth with divergent and completely developed roots were used in this study. Ethical approval for use of extracted teeth had been obtained (USM/JEPEM/1405213). The teeth were cleaned by immersion in 5% sodium hypochlorite for 30 min. All samples were then cleaned under running water and stored in normal saline until used. Silicone putty (3M ESPE Express^{TM} STD) were placed around the furcal area to simulate the periodontal ligament and stop the extrusion of material upon condensation or restoration. The teeth were decoronated 4 mm above cementoenamel (CEJ) and horizontally cut off at mid-root. Root canal orifice and apical end were sealed with composite resin (Filtek Z350 XT, CE).

A perforation was created in the furcal area using 012 round burs in a high-speed handpiece with copious of water. The width of the perforations was standardized to the diameter of the size 012 round burs whereas the length of the perforations depended on the dentine-cementum thickness in the furcation area. Four teeth were randomly selected from 68 teeth for control positive and control negative. The rest 64 teeth were randomly divided into four groups.

Sample treatments

Sixteen teeth were repaired from each group with ParaCore (Coltene Whaledent), GAUF (GCEurope), MTA (ProRoot MTA) and Biodentine (Septodont®, France) following manufacturers' instruction. For positive control, two teeth were prepared in the same manner as the experimental groups but receive no repair to the perforation. For negative control, two teeth were prepared in the same manner as the experimental groups but no perforation was made. The roots were completely covered by nail varnish except the furcation area.

Dye penetration and microleakage measurement

Teeth repaired with Biodentine and MTA were left for 6 h to set before immersion in 2% basic fuchsine whilst teeth repaired with ParaCore and GAUF were immersed after the setting of the material took place. All were immersed in 2% basic fuchsine for 24 h at 37 ^{0}C. The teeth were washed with tap water and sectioned longitudinally in a bucco-lingual plane in the centre of perforation, using a diamond blade in a dry condition with low speed machine. The teeth were washed with tap water and sectioned bucco-lingually, exactly at the centre of the perforation, using a diamond disc in a dry, low-speed handpiece. Dye penetration was measured from the apical end of the perforation to the pulp chamber using stereomicroscope (HIROX KH7700, Japan).

Morphological analysis

Two teeth as representative of each group were prepared for SEM evaluation. The samples were desiccated and mounted on 26 mm aluminium stubs using special double-sided conductive tapes. Samples then were coated with gold, an electrically conductive material applied using a sputter-coater machine for 5 min. The gaps between repair materials and dentine were observed under magnification of 3500x.

Statistical analysis

The microleakage data were analysed with Median's by ranks at a 95% level of confidence for pairwise comparisons. P value of less than 0.05 was considered as statistically significant.

Results

Median tests were used to compare percentage of dye penetration between perforation repair materials since Shapiro Wilk indicated non-normal distribution in the data (p<0.001). Complete dye penetration was observed in positive control. In contrast, negative control group did not show any dye penetration. ParaCore shows no leakage, while GAUF shows minimal leakage and both Biodentine and MTA show full dye penetration (Figure 1). The percentage of dye penetrations were significantly higher in MTA and Biodentine than in injectable composite resins groups (p<0.001). In MTA and Biodentine samples, the dye appeared to be absorbed throughout the materials whereas in ParaCore samples, the dye penetration was seen along the interface between the material and tooth surfaces.

Pairwise comparisons of the percentage of the microleakage show statistically difference between ParaCore and GAUF (p<0.001), Paracore and MTA (p<0.001), ParaCore and Biodentin (p< 0.001), GAUF and MTA (p<0.001), GAUF and Biodentin (p<0.001).

Variation in dentine cementum thickness of all samples are shown in Table 1. Samples in GAUF group demonstrated more numbers of samples with thicker dentine cementum thickness compared to ParaCore group. This is significant finding for both group in which setting of the materials depend on the distance of light curing source.

Range of dentine cementum thickness (mm)	Number of ParaCore samples	Number of GAUF samples	Number of Biodentine samples	Number of MTA samples
0.0-1.0	4	2	2	3
1.1-2.0	6	6	4	5
2.1-3.0	5	7	7	6
3.1-4.0	1	1	3	2

Table 1. Thickness of dentine-cementum.

Morphological analysis

Good adaptation was noted between both injectable composites Paracore (Figure 2(a)) and GAUF (Figure 2(b)) with the tooth surface whereas present of gap between material and tooth surface for both Biodentine (Figure 2(c)) and MTA (Figure 2 (d)). Injectable composite resins also demonstrated less gap at material tooth interface under SEM.

Discussion

Should a furcal perforation occur, the outcome is favourable if the perforation is immediately sealed. Nevertheless, the choice of the sealing material plays a major role as it influences the clinical outcome. A good sealing material prevents any microleakage or bacteria invasion from occurring hence increasing the chance of tooth survival. Thus, it is crucial to find a material that can best sealed the perforation.

Microleakage is defined as presence of micro gap between the restorative margins and tooth surfaces whereby bacteria and its toxin is able to travel along this interface.[15] Several models have been utilized to assess microleakage. These models include dye penetration, fluid filtration, protein leakage and bacterial leakage.[16-18] One of the most common models used at present is the dye penetration technique. This technique does not require any sophisticated materials and it is easy to perform. The dye penetrates the resin-dentin interface wherever gaps occurred. According to Torabinejad and colleagues, any material that is able to prevent the penetration of a small molecule (dye) should be able to prevent larger substances like bacteria and their by-products.[19] The degree of dye penetration represents the extent of micro gap between the restorative margin and tooth surfaces that would permit bacteria and their by-products to travel along this interface. Dye used in this study is basic fuchsine. It is a fluorescent dye composed of rosaniline, magenta II, pararosaniline and new fuchsine. It is dark green powder that will turn red in solution with molecular weight of 337.85 g/mol. The molecular size of basic fuchsine is about 1 to 2 nm, which is smaller than bacteria (0.5–1µm). No penetration of the sample when subjected to basic fuchsine dye represents a very good adaption of the materials to tooth structure resulting in prevention of the bacteria ingression.[20]

Prior to the test on experimental groups, the positive and negative control samples have been verified to validate the method used in this study. Positive control samples demonstrated full dye penetration whereas the negative control samples showed no dye penetration at all. This has confirmed the use of nail polish to completely resist dye penetration.

In this study, MTA was used as a gold standard since it had been proven to be a suitable sealant material and highly biocompatible.[10,21,22] Several studies had shown success in treating furcal perforations incidents with the use of MTA.[23-26] Not only MTA had been proven to have the capability to induce cementum deposition but it was also recognised to have superior sealing ability compared to other restorative materials when used to repair perforation.[27] Biodentine is similar to MTA with regards to its composition and dental applications. It was claimed by the manufacturers to have improved physical properties compared to MTA.

However, the result of the study indicated that there was a full dye penetration in all samples of Biodentine and MTA. On a closer look, the pattern of microleakage for Biodentine and MTA samples differs from that of ParaCore and GAUF. The microleakage seen in both ParaCore and GAUF samples were confined to tooth-material interface, whereas MTA samples showed a complete absorption of dye throughout the entire material. Full penetration of dye in Biodentine and MTA samples could be attributed to the length of duration after repair was performed to the time of immersion. A study done by Haghgoo and colleagues demonstrated that the samples were left to set for 72 hours whilst Nikoloudaki and colleagues has left their samples for 28 days before immersion occurs.[28,29] Maybe both techniques will ensure that both materials are fully set before leakage experiment was done. In this study, only 6 hours was taken for both Biodentine and MTA to achieve complete setting prior to immersion in the dye to simulate closely the clinical scenario. Full penetration might indicate partial setting of the materials when subjected to dye penetration test.

Another explanation of full dye penetration throughout all samples of Biodentine and MTA could be attributed to the microporous structure of both materials and their water soluble nature prior to achieving full setting.[30] Being a hydrophilic aggregate materials, both require moisture for its setting reaction to take place,[31] hence in cases of in vitro study in which the teeth are lacking moisture, the materials may have acquire moisture from the dye itself. Similar findings were also shown in other studies, where MTA did not resist any microleakage.[32-34]

Among the materials that have the potential to be used as repair material are injectable composite resins namely GAUF and ParaCore as being used in the current study. The low viscosity of these injectable composites may enhance its wetting capacity resulting in a more interfacial internal adaptation and lower formations of void.[35] However, numerous factors such as the type of resin material used, the characteristics of cavity prepared and the method adopted, have been shown to influence the microleakage which in turn reflects the success of the restoration.[36,37] One of the main factors that can affect microleakage in dental composite is the extent of polymerization shrinkage. Polymerization shrinkage results in the breakage of the bond between the tooth surface and the repairing material used creating micro gaps which leads to microleakage.[37] The degree of polymerization shrinkage occurred is influenced by the percentage of matrix and the filler and the technique used.[38] According to Kikushima and colleagues, the adhesive system showed lower bonding strength to cementum compared to dentin.[39] This could be due to the existence of coarse collagen fibres which had caused less or non-homogenous penetration of resin monomers into the etched zone. Due to the weaker bonding of the composite to cementum, the material might have been displaced towards the direction in which it was more strongly bonded to, in this case, the dentin, thus creating micro-gaps.

From the current study, both injectable composite resin materials showed significantly less leakage compared to Biodentine and MTA whereby between the two injectable materials, Paracore has the least leakage. Paracore is claimed by manufacturer to be used for situations where light might not be able to penetrate, such as deep cavities, metal crowns, post cementation, or opaque ceramic. Furcal perforation is also an example of similar condition where light might not be able to reach the end of perforation. Most of the samples that received ParaCore as repair material showed minimal leakage. This is possibly due to its feature as dual cure composite which possess both chemical and light cured system to ensure a complete polymerization takes place. It contains component that provide rapid polymerization in areas where curing light penetrates effectively whilst a slower chemical polymerization will still take place in the remaining areas. In this study, ParaCore demonstrated superior sealing ability than GAUF. This finding was supported by another study in which they demonstrated the importance of a material to have both features, dual cure and flowability to be superior in sealing ability.[40] In their study, RMGIC which has both features showed a better sealing ability compared to light cured composite. In addition, the flowability of dual-cure composite of ParaCore may have provided better adaptation to the walls of the preparation, potentially reducing microleakage. Another study was done to compare the properties of two new dual-cured composite resins with a hybrid composite resin material. They found that the new dual-curing restorative materials could slower the polymerization shrinkage hence reducing the stress applied at the tooth interface and subsequently decrease marginal gap formation.[41]

However, there were some samples from GAUF group demonstrated dye penetration to half of dentine-cementum thickness indicating presence of microleakage. It may be due to insufficient light reaching the deepest part of repaired area which can result in partial polymerization of the GAUF samples. In the current study, there were some variation in the anatomy of the tooth particularly dentine-cementum thickness of the samples tested which can lead to possible incomplete polymerization of GAUF samples with larger dentine-cementum thickness (Table 1). Area of material closer to the source of light will be completely cured however the areas away from the source of light possibly might end up being uncured or partially cured.

Evaluation of marginal adaptation of Paracore (Figure 2(a)), GAUF (Figure 2(b)), Biodentine (Figure 2(c)) and MTA (Figure 2(d)) were done under Scanning Electron Microscope (SEM) at the magnification of 3500x. ParaCore and GAUF showed minimal gap formation compared to Biodentine and MTA. It can also be observed that MTA gap is also larger than Biodentine. The same finding also was also found by Samuel and colleagues, in which the MTA showed more gap than Biodentine™ under SEM evaluation when used to repair furcal perforation in primary molar. However, from this study, it can be concluded that there was better marginal adaptation of Paracore and GAUF in comparison to Biodentine and MTA.

Conclusions

This study highlights the potential of the injectable materials namely ParaCore and GAUF to repair the site of perforation as they seal significantly better. The results show both ParaCore and GAUF materials have lower dye penetration than Biodentine and MTA when used in repairing furcal perforation area of molar teeth.

Acknowledgements

This research was supported by Research and Innovation Division, Universiti Sains Malaysia, short term grant 304/PPSG/61313117.

Declaration of Interest

The authors report no conflict of interest.

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