Fracture Resistance of Immature Roots Obturated with Three Different Filling Materials

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Abstract: The purpose of this study was to compare the fracture resistance of immature roots having apical plug with Portland cement (PC) together with obturation using (i) Zinc Oxide based sealer (ii) Epoxy resin based sealer used with lateral compaction of gutta-percha (iii) Total obturation with Portland cement. Twenty five single rooted teeth were randomly assigned into three experimental groups according to the filling material and one control group. The control group was subdivided into a negative control with unprepared teeth and a positive control with unobturated immature teeth. Teeth in all groups except the negative control were prepared to stimulate immature roots. Root ends in the three experimental groups were filled with a 4 mm barrier of PC. Then the canals were obturated using the three selected materials. Fracture resistance testing was performed using a universal testing machine after embedding teeth in artificially prepared sockets. Fracture load value was measured in Newtons (N) and the fracture pattern was determined. Results indicated that ZnO/E exhibited the highest mean fracture load values, followed by PC, then Ez-Fill. The positive control group showed the least mean fracture values. However ANOVA test revealed no significant differences between all groups (P=0.06). It was concluded that, the use of ZnO/E, or Ez-Fill with gutta-percha core material, as well as, total filling with PC compensated the reduced strength from the lost dentin substance in the simulated immature teeth with PC apical plug.
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I. Introduction

The clinical management of cases with incomplete root development and periapical pathosis is challenging because of the open, divergent apical morphology , weak, thin, fragile, underdeveloped root dentin walls, Bortoluzzi et al.,(2007). These features make instrumentation of the canal difficult and hinder the formation of an adequate apical stop. Endodontically treated teeth with immature root formation might have cervical fractures due to minor impacts, Çobankara et al.,(2002); Carvalho et al.,(2005).

Sometimes even spontaneous fractures occur. Vertical root fractures following endodontic treatment represented 10.9%, Fuss et al.,(1999). One of the treatment options of immature teeth induces apical stop by apexification. However, the reduction of fracture resistance strength is still questionable.

Materials that can adhere to the root canal dentin surface may strengthen the remaining tooth structure, Johnson et al.,(2000); Teixeira et al.,(2004); Bortoluzzi et al.,(2007); Kıvançal.,(2009). Adhesion and/or mechanical interlocking between the sealer material such as glass ionomer and epoxy resin type and the root canal dentin will not only prevent microleakage but also may increase the fracture resistance, Goldberg et al.,(2002); Çobankara et al.,(2002); Ulusoy et al.,(2007).

Over the time, there has been a continuous search for dental materials that present an ideal combination of good mechanical, physicochemical and biological properties concerning the induction of apexogenesis and control of periapical involvement. Calcium hydroxide has been used as intracanal medication for apexification or microbial control. Alternatives to calcium hydroxide have been proposed, the most promising being a recently developed material, mineral trioxide aggregate (MTA) and Portland cement. The fracture resistance strength was significantly higher with MTA compared to $Ca(OH)_2$, Andreasen et al.,(2006); Hatibović-Kofman et al., (2008). Total filling with MTA had significantly higher fracture resistance, Ulusoy et al., (2007).There is a possible clinical use of PC as an option to MTA, De-Oliveira et al., (2007).Whether total obturation of the canal with Portland cement would affect the fracture resistance of immature roots is still to be investigated.

Therefore, one of the aims of filling such root canals was to select the proper material that help in increasing the fracture resistance. As well as, to compare the fracture resistance of immature roots having apical plug with Portland cement together with obturation using :

(i)Zinc Oxide based sealer.

(ii) Epoxy resin based sealer used with lateral compaction of gutta-percha.

(iii) Total obturation with Portland cement.

2. Materials and Methods

2.1. Materials:

2.1.1.Sample of the study:

Twenty five extracted single rooted human teeth with a single canal were selected.

-Teeth selection and grouping

Only the teeth with intact crowns at least 4mm above cemento-enamel junction were included. The mesio-distal (MD) to bucco-lingual (BL) ratio at the cemento-enamel junction (CEJ) was determined and teeth with excessive BL: MD ratios were excluded. Their roots were examined for any cracks or caries using Stereomicroscope (CARLZEISS / JENA – Technival 2- Germany) at 10x magnification. The root surfaces were thoroughly cleaned then stored in sterile saline containing 0.2% sodium azide at room temperature, Apicella et al.,(1999); Johnson et al.,(2000); Teixeira et al.,(2004); De-Deus et al.,(2008).

Each tooth was numbered then stored in a coded eppindorf. The teeth were randomly assigned into three experimental groups (n=5) according to the filling material and one control group (n=10).

**In the experimental group (1)*:

Teeth were obturated using zinc oxide eugenol based sealer (ZnO/E) (Endofill; DENTSPLY; Maillefer, Rio de Janeiro, RJ, Brazil).

**For the experimental group (2)*:

Teeth were obturated using Ez-Fill (Essential Dental Systems, South Hackensack, NJ, USA).

**In experimental group(3):*

Teeth were obturated using (PC) (White Portland cement, CEM I 52.5N, Helwan cement, Cairo, Egypt).

**The control group* was further subdivided into two subgroups (n = 5), a negative controls with unprepared teeth and a positive controls with unobturated immature teeth.

2.2. Methods:

2.2.1. Preparation of simulated immature teeth:

Root length was measured from cemento-enamel junction to a standard length of 12 mm. Diamond disc was used to cut root apexes exceeding the 12 mm. The crown length was shortened leaving 4 mm above CEJ with a flattened surface perpendicular to long axis of tooth (Figure 1). An endodontic access cavity was then prepared; canal patency was checked by inserting K file (MANI, INC, Japan) size 15 into the canal until it was observed from the cut apex. Different sizes of Pesso-drill files 1, 2, 3, 4, 5 were used for root canals instrumentation to a size #150 pesso drill (MANI, INC, Japan, MEDIN: Czech Republic). Canal diameter was set at 1.5 mm diameter; then teeth were re-examined for the development of cracks or fractures after preparation using stereomicroscope. Sodium hypochlorite (NaOCl), 5ml 17% Ethylenediamine Tetra-acetic acid solution (EDTA), and then 5ml distilled water were used for teeth canals irrigation and smear layer removal. Each irrigant was applied for 3 min. This irrigation regimen was done to all experimental groups except for PC group.

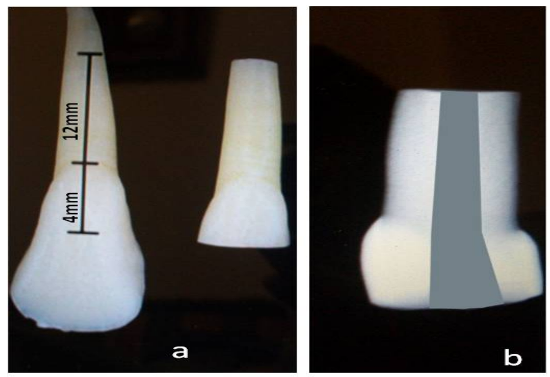

Figure 1. Immature model preparation of samples. (a) Length adjustment. (b) After preparation of the simulated canal using pesso drill up to size 5 (1.5mm).

2.2.2.Application of apical PC plug:

One hundred grams of purchased raw white Portland cement (PC) was weighed. PC powder was ground and sieved by standard sized sieves to gain particle sizes similar to that of MTA,Table (1). Different particle sizes were prepared, mixed then sterilized for one hour in a hot air oven at 180ºC, Mohamed (2006). The prepared cement was then divided into portions of 1 gram and placed in sealed glass test tubes.

Table 1. The distribution of particle sizes between 0.5-30 µm for MTA.(Soheilipour et al 2009)

Particle size range (Unit µ)	MTA %
0.5-2.5 µ	13
2.6-4 µ	12
4.1-6 µ	16
6.1-15 µ	26
15.1-30 µ	19

One gram PC powder was mixed with 0.4 ml distilled water, De-Deus et al.,(2008); Saliba et al.,(2009). The mixture was then passed to the teeth orifices using amalgam carrier and condensed to the apical third of the canal using plugger number 3 (ASA Dental Spa, Via Valenzana, Italy) with adjusted rubber stoper to ensure 4 mm thickness of the apical plug. Each apical plug consumed quarter gram of PC mix. A moisten cotton pellet was then placed inside the root canal above the plug to ensure canal moistening. Another one was wrapped around the apex and the tooth was wrapped with dampen gauze to ensure 100% humidity. The teeth were then placed into the incubator at 37ºC for 72 hours.

2.2.3.Teeth obturation

Smear layer removal was done by sequential irrigation using the same previously mentioned irrigation regimen.

The prepared teeth in the experimental group (1) and (2) were obturated using Endofill and Ez-Fill respectively according to the manufacturer instructions. While for the experimental group (3), the root canal was left moist and one gram Portland cement powder was mixed with 0.4 ml distilled. The mix was then carried with amalgam carrier and pressed with plugger no. 3. A moisten cotton pellet was placed inside the access and all root specimens were stored in 100% humidity for 72 hours in their coded epindorfs to allow the sealer and PC to set completely.

The root canals were then filled with Gutta-percha (Dia-Dent; Diadent Group International, Netherlands) No.80 using lateral compaction technique using size 25 finger spreader (MANI, INC, Japan) with adaptation of auxiliary cones size 25. The access cavity was sealed with temporary filling. Teeth were examined radiographically to verify the obturation quality,Figure (2). For the control groups, teeth were left without obturation. A cotton pellet was placed at a level of the facial CEJ and the root canal opening was sealed with a temporary filling material.

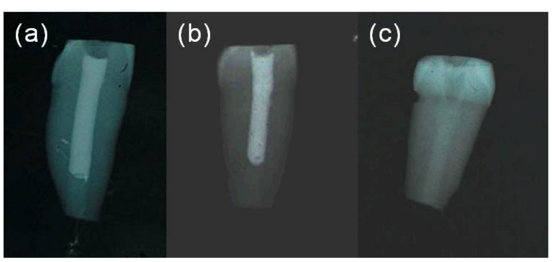

Figure 2. Radiographic verification of teeth after obturation using: (a) ZnO/E, (b) Ez-Fill, (c) PC.

2.2.4. Fracture resistance testing

The roots of the teeth were wrapped in a single layer of lead foil from a periapical x-ray film to 2 mm below the cemento-enamel junction. They were embedded in separate standard Teflon cylinder mould (25mm height×19mm external diameter×14mm internal diameter) filled with polyester resin (Acrostone, Cairo, Egypt) to create artificial sockets. Protractor was used to ensure that the long axis of the root was aligned vertical. After the setting of the resin the lead foil was removed, light body silicone (ISO 4823, Type 3, low consistency, Speedex light body, (Coltene/Whaledent) was mixed according to the manufacturers' instructions and was injected into the socket to provide a simulated periodontal ligament. The root was repositioned carefully so that only the apical 10 mm of the root was mounted in the resin. The physiologic relationship between the bone crest and tooth was simulated by leaving a 2mm gap between the top of the acrylic and the facial cervical line, Lertchirakarn et al.,(2002); Carvalho et al.,(2005); Stuart et al.,(2006).

Each specimen was placed into a universal testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK) that applied a shearing load at 135° angle to the long axis of the root in a lingual-labial direction at the level of the lingual CEJ, Carvalho et al.,(2005); Stuart et al.,(2006).

Load was applied at a crosshead speed of 0.5mm/minute. Specimens were loaded until fracture and the load at the failure was measured in Newtons (N). The fracture pattern was also determined.

2.2.5.Statistical analysis

Non Parametric statistical analysis was done using Kruskal- Wallis test for comparing more than two groups. For two groups comparison Wilcoxon (Mann-Whitney) test for unpaired data was prepared. Statistical significance was set at $P > 0.05$ using KyPlot software version 2.0 beta 15.

3.Results

3.1. Effect of different filling materials on fracture resistance

The mean fracture load values (N) ± standard deviation in different filling materials groups are presented in table(2). Results indicated that ZnO/E exhibited the highest mean fracture load values, followed by PC, then Ez-Fill. The positive control group showed the least mean fracture resistance values. However statistical analysis revealed no significant differences between all groups (P=0.06).

Results also indicated that the negative control group presented the higher mean fracture load values (2217.3±674.4 N) than the positive control groups (1294.0±157.8N).However statistical analysis revealed no significance difference between the two groups (P=0.11). It is worth mentioning that the mature unprepared teeth group exhibited mean fracture load values near to that of immature teeth filled using ZnO/E and PC.

Table 2.Mean fracture load values (N) ± standard deviation (SD) for different filling materials.

Group	Fracture load (N)	
	Mean	SD
ZnO/E	2044.0	±681.4
Ez-Fill	1690.2	±311.6
PC	2019.8	±768.6
Control +ve	1595.9	±711.3
P-value	0.06	

3.2.Mode of fracture

Representative samples showing different mode of fractures of different groups are shown in figure 3. Most of the experimental and control positive subgroup showed horizontal or oblique fractures through the cervical portion of the root. Only five teeth showed complex fractures. Negative control group showed one horizontal, one mutilated and three oblique fractures. The frequency distribution (n) of the mode of fracture of all the groups is presented in table (3). Group 1 filled with ZnO/E showed higher incidence of horizontal fractures versus oblique with no mutilated ones. Ez-Fill and PC groups showed equal incidence of horizontal and oblique fractures, with only one tooth in each group showed mutilated fracture. While the control positive group showed higher incidence of mutilated fractures

Table 3. Frequency distribution (n) of the mode of fracture of all groups.

	n	Mode of fracture		
		Horizontal	*Oblique*	*Mutilated*
ZnO/E	5	3	2	0
Ez-Fill	5	2	2	1
PC	5	2	2	1
Positive	5	1	1	3
Negative	5	1	3	1
Total	20	8	7	5

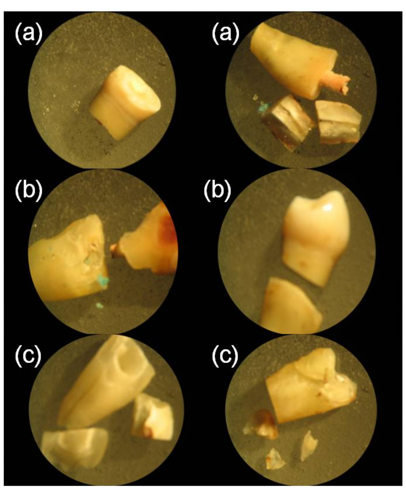

Figure3. Representative samples showing different mode of fractures of different groups. (a) Horizontal fracture. (b) Oblique fracture. (c) Mutilated(complex fracture).

4.Discussion

It is thought that the adhesion and mechanical interlocking between the sealer material and the root canal dentin prevents microleakage and reduces the risk of fracture. It is also suggested that materials that can adhere to the root canal dentin surface would strengthen the remaining tooth structure, Johnson et al.,(2000); Teixeira et al.,(2004). In the present study epoxy resin-based sealer was selected due to its ability to adhere to the root canal dentin surface, Al-Kahtani et al.,(2007); Jainaen et al.,(2009) . Portland cement was also selected in this study due to its postulated similarity in action to MTA, Torabinejad and Parirokh (2010). Previous studies indicated that MTA and PC were similar in their major constituents, Mohamed(2006); De-Oliveira et al.,(2007). Both MTA and PC are bioactive materials, Reyes-Carmona et al.,(2009). The biocompatibility of the materials had originally been attributed to the chemical similarity to tooth hard tissues, and also they had similar antimicrobial activity. However bismuth oxide was found in MTA but not in PC. Both materials provided a similar pH, but they differed in the amount of calcium ion release especially initially with white Portland cement (WPC) releasing the greatest amount. In spite of the chemical similarity, a difference in the texture and in the particle size was observed between MTA and PC, De-Oliveira et al.,(2007).In the present study, teeth were carefully selected for standardized size and absence of any root caries and cracks that may influence the resistance to fracture by acting as stress concentration areas. Attempts were made to avoid the development of cracks during gross tissue debridement, by using hand scalers rather than ultrasonic scalers to clean the root surfaces, Lang et al.,(2006); Pişkin et al.,(2008) and the use of sterile saline containing 0.2% Sodium azide rather than NaOCl as a storage media to avoid its effect on the mechanical properties of the examined teeth, Grigoratos et al.,(2001); Zhang et al.,(2010); Retamozo et al.,(2010). The teeth were used within three months from extraction time to preserve dentin hardness, Sedgley and Messer (1992).In this study, an experimental model that simulates immature non-vital teeth with weakened dentinal walls was prepared through reaming out of the whole length of the root canal of the mature teeth, Stuart et al.,(2006). Previous study done by Carvalho et al .,(2005) simulated only the wide immature canal in the cervical and middle thirds and left the apical third with the mature canal dimension. However, this was not followed in the present study because the apical part still represents the main problem in creating an apical stop.

Using apical plug and single step apexification has another advantage of overcoming the break of coronal seal during multi-visit treatment which might result in re-infection and prolongation or failure of treatment. The use of apical plug also provides an apical barrier, preventing the extrusion of root canal filling material into the surrounding tissues. It would also provide a restoration that reinforces the weak immature dentinal root walls reducing its potential to fracture. The technique of one-step apical plug and obturation offers effective and efficient results in apexification of immature teeth, allows for permanent restorations to be done in a more timely manner, prolonging the longevity of these teeth, Erdem and Sepet (2008).

The commercial PC powder was adjusted through grinding and sieving to gain finer particle sizes, as recommended by a previous study done by Primus(2005) which illustrated that removal of coarse particles, or reduction in the average particle size resulted in the improvement of dental materials performance. In theory using fine particle size can be also advantages when the size of the dentin tubules (2 to 5µm) correlates with the size of the PC powder particles. This makes it possible for PC to enter the open dentin tubules. The penetrating particles may act as a direct source of dissociated calcium hydroxide, resulting in a high local pH with only a slight chance of being reduced by dentin buffering. Higher pH would also result in a stronger and more effective antimicrobial action. Furthermore, the removal of particles coarser than 400 meshes (40 µm) would improve the handling characteristics of the cement. Another study done by Parirokh and Torabinejad (2010) showed that smaller particle size increase the surface contact area with the mixing liquid and lead to greater early strength as well as ease of handling.

Smear layer removal was done by sequential irrigation with five ml 5.25% concentration NaOCl, 5ml 17% EDTA then 5ml distilled water. NaOCl at 5.25% concentration was used because of its antimicrobial effect, Retamozo et al.,(2010) . It was used for only 3 min as the prolonged usage for 1-2 hours, would decrease the teeth flexural strength, Grigoratos et al.,(2001); Retamozo et al.,(2010); Zhang et al.,(2010).The combination of NaOCl (5%) and EDTA (10%–17%) is particularly effective in the removal of organic and inorganic debris without weakening the tooth, since EDTA is a chelator with calcium-depleting ability. It was only used for 3 min as its prolonged application reduces the microhardness of dentin, Primus(2005) In only two experimental groups, ZnO/E and Ez-Fill groups, smear layer was removed by the irrigation of a final rinse of 17% EDTA. Previous studies showed that EDTA when used as a final irrigant after NaOCl exhibited root canal walls mostly free of smear layer with open dentinal tubules and reduced the oxidizing effect of NaOCl on sealer polymerization, Primus(2005); Schäfer et al.,(2007); Hammad et al.,(2007). The removal of smear layer is thought to be important for resin-based materials for optimization of resin flow and penetration, and modification of the tubule wall to enhance bonding and thus hopefully increase the resistance to fracture. Smear layer was not removed with PC total obturation group, since MTA, as root canal filling material, showed significantly higher leakage when smear layer was removed, by using EDTA, before placing the MTA material, Torabinejad M, Parirokh(2010)

The EZ-Fill sealer was the epoxy resin based cement used in the present study. It is similar to AH-26 but much more radiopaque. It is also very biocompatible and it reported 94% success rate in an in vivo study, Deutsch(2010).

Attempts were made to simulate the periodontal ligament (PDL) and tooth supporting structures, by avoidance of any external reinforcement of the root structure using a light body silicone impression material. Although the PDL and the impression material have different physical properties, they present similar behaviour when submitted to external stress, i.e. the response is nonlinear and viscous. After setting, the elastomeric material is very close to the elastic modulus of human PDL, Bortoluzzi et al.,(2007);Saliba et al.,(2009).

Attempts were also made to simulate the clinical conditions where teeth are stressed not only vertically down the long axis of the root, but loading is also directed more likely at a certain angle. The vertical wedging forces applied in other researches , Apicella et al.,(1999); Johnson et al.,(2000); Goldberg et al.,(2002); Lertchirakarn et al.,(2002); ; Mohamed (2006);Hammad et al.,(2007); Al-Kahtani et al.,(2007); Pişkin (2008);Fuss et al.,(2009); Jainaen et al.,(2009); ; Karapinar et al.,(2009); (which primarily resulted in a splitting stress, was not justified in the present study. In this study, the force was applied at a 135° angle to the lingual wall.

Results of the present study showed that obturation of the canals with Ez-Fill did not significantly strengthen the roots compared with the other experimental groups. These results corroborate those of several studies using gutta-percha and an epoxy resin– based sealer, Lertchirakarn et al.,(2002); Teixeira et al.,(2004); Schäfer et al.,(2007) Contradictory results were reported in other studies which found that the use of the epoxy resin– based sealer resulted in a significant strengthening of the instrumented roots, Çobankara et al.,(2002); Ulusoy et al.,(2007); Jainaen et al.,(2009); Karapinar et al.,(2009) .These divergent results may be attributed to different testing methods (for example; using different loading angle, point and rate of loading). This discrepancy might also be due to the differences in teeth extraction time, dimensions of the teeth, biomechanical instrumentation, experiment design, and operator influence.

In the present study, total filling with PC had significantly higher fracture resistance values than control unfilled immature teeth which was similar to the values obtained in a previous study done by Bortoluzzi et al.,(2007). Also it had high fracture resistance values in relation to the other experimental groups. This might be due to the diffusion controlled reaction between cement, apatite layer and dentin, which would be responsible for their chemical bonding, Reyes-Carmona et al.,(2009);Parirokh and Torabinejad(2010).

The cement released some of its components, triggering the initial precipitation of amorphous calcium phosphates, which acted as precursors during the formation of carbonated apatite. This spontaneous precipitation promoted a biomineralization process that leads to the formation of an interfacial layer with tag-like structures at the cement-dentin interface, Reyes-Carmona et al.,(2009) . In the present study, immature unfilled group was weaker than mature intact group and this confirmed that any substance loss or any modification of natural root canal geometry would affect tooth strength, Lang et al.,(2006) .Also, fracture resistance was affected largely by the remaining dentin thickness, Çobankara et al.,(2002);Kıvanç et al.,(2009). The importance of placement of filling material to substitute the lost part of the tooth was thus reassured. In all experimental groups, there was no statistical significant difference between them or with the control intact teeth. This might be reflection that the filling compensated the reduced strength from the lost dentin substance.

Further researches are still recommended to investigate new materials and techniques aiming to increase the fracture resistance in immature unfilled teeth.

Conclusion

Within the limitations of the present in vitro study, it could be concluded that, the use of ZnO/E, or Ez-Fill with gutta-percha core material as well as total filling with PC compensated the reduced strength from the lost dentin substance, in the simulated immature teeth with PC apical plug.

5.References

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