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FRACTURE RESISTANCE OF ROOTS OBTURATED WITH BIOCERAMIC AND EPOXY RESIN- ROOT CANAL SEALERS USING DIFFERENT OBTURATION TECHNIQUES: AN EX-VIVO STUDY

Nermine Hassan* *and* Reham Hassan**

ABSTRACT

Aim: The aim of this study was to compare the fracture resistance of endodontically treated teeth obturated with two root canal sealers using two different obturation techniques.

Materials and methods: Forty freshly extracted single-rooted mandibular premolars were selected, decoronated, and mechanically prepared using EdgeFile X7 rotary files to size 40/0.04. Samples were randomly divided into 4 groups (n=10). In Group I: samples were obturated with AH Plus resin sealer using cold lateral compaction technique, Group II: samples were obturated with AH Plus resin sealer using single cone technique, Group III: samples were obturated with NeoSealer Flo bioceramic sealer using cold lateral compaction technique and Group IV: samples were obturated with NeoSealer Flo sealer with single cone technique. Fracture resistance testing was done using a universal testing machine. The data were analysed statistically using one-way analysis of variance followed by pair-wise comparison using Tukey's post hoc test.

Results: Neosealer Flo samples had significantly higher fracture resistance than AH Plus samples ($p<0.001$). Regardless of type of sealer used, single cone obturation technique had significantly higher fracture value than lateral compaction ($p<0.001$).

Conclusion: Obturation using NeoSealer Flo sealer with single cone technique improved the fracture resistance of endodontically treated teeth.

KEYWORDS: NeoSealer Flo sealer, AH Plus sealer; Single cone technique; cold lateral compaction technique; Fracture Resistance.

* Lecturer, Department of Endodontics ,Faculty of Dentistry, Cairo University
** Associate Professor, Department of Endodontics, Faculty of Dentistry, Minia University.

INTRODUCTION

During the past 10 years, there has been an increasing awareness of vertical root fracture (VRF) occurring after endodontic treatment. The third most prevalent reason for extraction of endodontically treated tooth is VRF [1]. The strength of teeth treated endodontically is influenced by tissue loss both coronal and radicular due to prior pathology or trauma, endodontic treatment including over-instrumentation, irrigation, medicaments, and excessive pressure during root obturation which eventually increase the possibility of tooth fracture [2].

Obturation of the root canal is thought to reinforce the tooth by increasing the resistance of the tooth to compressive strength, it would be beneficial to use a root canal filling material and/ or sealer which is capable of strengthening the root. Gutta-percha is known to have a low elastic modulus which offers little or no reinforcement after treatment [3].

AH Plus (Dentsply DeTrey, Konstanz, Germany) is an epoxy resin-based sealer that can penetrate into the dentinal tubules with the possibility of creating monoblocks between intraradicular dentine and root canal filling material which increase the resistance to fracture by preserving the integrity of the sealer-dentine interface [4, 5].

NeoSealer Flo (Avalon biomed, Texas, USA), a premixed bioceramic sealer that encourages the production of hydroxyapatite on the surface to seal and facilitate healing through the release of calcium and hydroxide ions as claimed by the manufacturer [6,7].

Single cone obturation technique (SCT), a technique based on the use of a single fitted cone with the same size and taper as the last rotary file used in combination with a large amount of sealer [8] has been considered inadequate due to the increased possibility for apical leakage [9] and deemed inferior to the lateral compaction technique (LCT) [10]. In 2009, a survey was conducted to compare different treatment modalities in endodontic practices, out of 232 respondents, (48.2%) reported using the continuous-wave of obturation technique, (43.6%) used LCT, where only (3.2 %) used SCT [11]. Conversely, in a recent survey with the advent of hydraulic cement-based sealers, 85.4 % used calcium silicate-based sealers where the acceptance of SCT has increased as it has leaped to be the most employed obturation method (63.3%) [12].

The present study was undertaken to compare the fracture resistance of endodontically treated teeth using two root canal sealers namely NeoSealer Flo, and AH Plus sealer with two obturation techniques (SCT and LCT). The null hypothesis was that there is no significant difference between the fracture resistance of the root canals filled with either techniques using NeoSealer Flo sealer or AH Plus sealer.

MATERIALS AND METHODS

Sample size calculation:

A power analysis was designed to have adequate power to apply a statistical test of the null hypothesis that there is no difference between different tested groups regarding fracture resistance. By adopting an alpha (α) level of 0.05, a beta (β) level of 0.2 (2%) (i.e. power=80%), and an effect size (f) of (0.605) calculated based on the results of an earlier study [13]; the minimum required sample size (n) was found to be (36) samples (i.e. 9 samples per group). To account for any sample loss, sample size was increased to (n = 10) for each group. Calculations were performed using G*Power version 3.1.9.2[14].

Selection of samples

The research proposal was approved by the Ethical Committee of the Faculty of Dentistry, Cairo University (Registration no. 22/11/22). Freshly extracted human intact mature straight single-rooted mandibular premolars were collected from the Department of Oral and Maxillofacial surgery extracted for orthodontic reasons, age group (18-35 years). Buccolingual and mesiodistal preoperative radiographs were taken to confirm the absence of any exclusion criteria which included calcifications or open apices, teeth with previous endodontic treatment or heavily restored teeth and those showing signs of resorption (internal or external resorption) and to ensure the presence of only one canal. To exclude the presence of pre-existing root fractures or cracks, teeth were examined under magnification (6X Univet Loupes, Rezzato, Lombardy, Italy). The buccolingual and mesiodistal diameters of teeth were measured at the level of the cemento-enamel junction (CEJ) using a digital caliper. Roots of similar dimensions measuring 4±1 mm mesiodistally and 5±1 mm buccolingually at the level of the (CEJ) were chosen. Sixty teeth fulfilling the inclusion criteria were chosen and stored in 0.1% thymol until the commencement of the experiment.

Sample preparation

Teeth were decoronated at the CEJ using a diamond saw mounted on a low speed micromotor under water coolant to adjust the length of the roots to a standard length of 13 mm±1mm. The working length was visually determined by introducing a size 10 K-file (EdgeEndo, Albuquerque, New Mexico) into the root canal until its tip was observed at the apical foramen; and then subtracting 1 mm. Samples were prepared using EdgeFile X7 (EdgeEndo, Albuquerque, New Mexico) rotary files up to size # 40/0.04 taper using an Endo-Mate 2 motor (NSK Nakanishi, Tochigi, Japan). The speed and torque values were set as the manufacturer's instructions. In between each file the canals were thoroughly irrigated with 2mL of 2.5% sodium hypochlorite (NaOCl; Clorox, HC Egyptian company, Cairo, Egypt), using a 30-gauge needle (Endo Top irrigation needles, Cerkamed, Pawłowski, Poland) adapted to a disposable plastic syringe. After the last instrument was used, each canal was irrigated with 5ml of 2.5% NaOCl, 5 mL saline followed by 5 mL of 17% EDTA (Cerkamed, Pawłowski, Poland) and a final flush of 5 mL saline and dried with paper points (Dentsply Sirona, York, Pennsylvania).

Sample grouping:

The selected samples were randomly divided using (https://www.randomizer.org) into 4 equal groups (n=10) according to the obturation technique and the sealer used into:

Group I: Samples obturated with AH Plus sealer/ LCT.

Group II: Samples obturated with AH Plus sealer/ SCT.

Group III: Samples obturated with NeoSealer Flo sealer/ LCT.

Group IV: Samples obturated with NeoSealer Flo sealer/ SCT.

Root canal obturation

Group I: AH Plus sealer/ LCT

AH Plus resin sealer is supplied in two tubes and was manually mixed in equal volume (1:1) on a glass slab using a metal spatula following the manufacturer's instructions. A gutta-percha cone size 40 taper 2% with tug-back was coated with the sealer and introduced into the canal by a slowly up and down movement against the canal walls until the working length was reached to ensure complete coating of the canal walls with the sealer. The cone was then removed and reloaded with the sealer and permanently seated into the canal. Lateral condensation was done using finger spreader size 30 adding accessory cones size 25. The excess was cut off at the orifice level using a hot instrument and lightly compacted with a plugger.

Group II: AH Plus resin sealer/SCT

The canals were obturated with a size 40/0.04 gutta-percha cone and AH Plus sealer. The sealer was mixed and applied as previously described in group I.

Group III: NeoSealer Flo sealer/LCT

NeoSealer Flo was supplied in a premixed injectable syringe with disposable intracanal tips. The canals were obturated with a size 40 taper 2% gutta-percha master cone. The sealer was injected into the coronal one third of the canal by a disposable intracanal tip. Obturation was carried out as in group I.

Group IV: NeoSealer Flo sealer/SCT

The canals were obturated with a size 40/0.04 GP gutta-percha cone and NeoSealer Flo premixed sealer. The sealer was injected into the coronal one third of the canal by a disposable intracanal tip, obturation was carried out as previously described.

After obturation, 1 mm of the coronal filling materials was removed, and filled with a temporary filling material (Cavit; 3M ESPE, Seefeld, Germany). To confirm complete filling, mesiodistal and buccolingual periapical radiographs were taken and then the samples were stored for one week at 37°C at 100% humidity to allow for complete sealer setting.

Mechanical testing

To mimic the periodontal membrane, the protocol proposed by Topçuoğlu et al. (2013) [15] was adopted, in which the apical 5 mm of the roots were covered with a 0.2-0.3 mm thick coating of wax. After that, self-curing acrylic resin (Acrostone dental factory, Industrial Zone, Salam City, Egypt) was used to install the roots vertically in copper rings that were 20 mm in diameter and 10 mm high, exposing the remaining coronal 8 mm of the roots. As soon as the acrylic resin began to polymerize, wax was removed using a curette and roots were taken out of the resin. The cleaned root surfaces were covered with a thin layer of polyvinylsiloxane impression material (Elite HD, Zhermack, Italy) and then they were embedded again into the acrylic mold.

Fracture resistant was measured using a universal testing machine (Instron Corp, Canton, MA). The acrylic blocks were fitted on the lower plate of the machine. The spherical steel tip of the upper plate (diameter of 2.2 mm) was centred over the canal orifices and aligned to be parallel to the long axis of the tooth, the tester was directed with a speed of 1 mm/min. The fracture moment was identified when an abrupt decrease in force occurred that was spotted on the testing machine screen. The maximum force required to fracture each specimen was recorded in Newtons. The load of fracture in Newtons was converted to Megapascal using the following equation.

$$\text{MPa} = \frac{\text{Maximum load in Newtons (N)}}{\pi / 4 \text{ x (Area of cross section of plunger of contact)}^2}$$

- π = 3.14 (constant value)
- Area of cross-section of plunger = 2.2 mm (uniform for all specimens).

All root canal preparations and obturation were performed by the same operator. Mechanical testing was performed by another examiner who was blinded to all the experimental groups. The mean and standard deviation values were calculated for each group.

Statistical analysis:

Numerical data were represented as mean with 95% confidence intervals, standard deviation (SD), minimum and maximum values. Shapiro-Wilk's test was used to test for normality. Homogeneity of variances was tested using Levene's test. Data showed parametric distribution and variance homogeneity and were analyzed using two-way ANOVA. The significance level was set at $p<0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.3.0 for Windows.

RESULTS

NeoSealer Flo sealer group using single cone technique (group IV) showed the highest fracture resistance mean value that required a load of (418.64±26.32N) to fracture the specimens which was statistically significant compared to other three groups (P *<0.001*), followed by Group II (385.8±10.38N) AH Plus resin sealer for single cone technique (Table 1).

Regardless of the obturation technique used, Neosealer Flo samples (356.56±66.28N) had significantly higher fracture resistance than AH plus samples (327.01±60.64N) (p<0.001) (Figure 1). In addition, regardless of type of sealer used, single cone obturation technique (402.11±25.82N) had significantly higher fracture resistance than lateral compaction (281.46±14.22N) (p<0.001) (Figure 2).

TABLE (1) Intergroup comparisons

Sealer type / *Obturation technique*	*Mean±SD (N)*		*f-value*	*p-value*
	AH Plus	*NeoSealer Flo*		
Lateral compaction technique	268.43±5.59	294.49±4.26	**15.98**	**<0.001***
Single cone technique	385.58±10.38	418.64±26.32	**25.72**	**<0.001***
f-value	**322.94**	**362.71**		
p-value	**<0.001***	**<0.001***		

****Significant (p<0.05)***

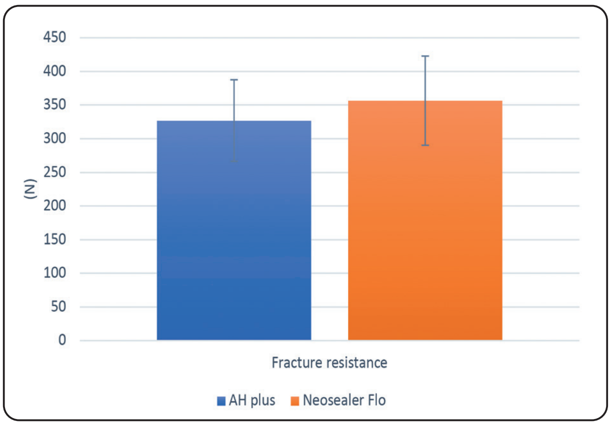

Fig. (1) Bar chart showing mean and standard deviation values (error bars) of fracture resistance for different sealers.

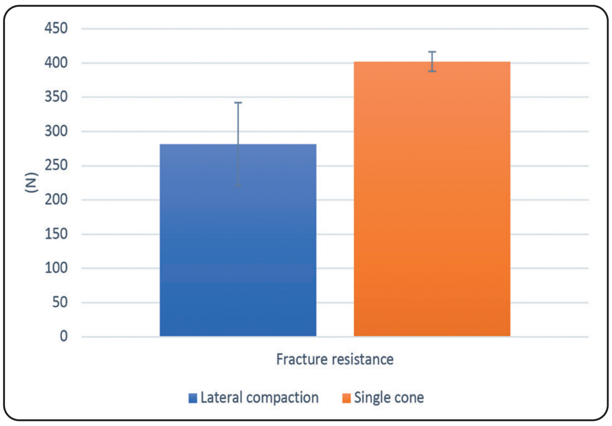

Fig. (2) Bar chart showing mean and standard deviation values (error bars) of fracture resistance for different obturation techniques.

DISCUSSION

Contemporary endodontic philosophy switches towards conserving the tooth structure by minimizing the amount of tooth structure removed, leaning towards smaller access cavities, avoiding aggressive dentine removal during shaping with more emphasis on irrigation, and avoiding wedging forces during compaction. This is considered as an important variable responsible for the outcome of endodontically treated teeth [16]. This study compared the fracture resistance of endodontically treated teeth obturated with different techniques and sealers.

According to published research, mechanically prepared but unfilled roots are significantly weaker than obturated roots, thus more prone to fracture [5], and that the root filling materials could strengthen the root structure, increasing the fracture resistance of the tooth [17].

In the current study, trials to achieve standardization of the samples included selecting samples with the same buccolingual and mesiodistal dimensions to homogenize the remaining dentine thickness [15] and age of the patient from whom extracted teeth were collected to avoid cracked teeth, as the incidence of incomplete tooth fractures was higher in patients over 40 years old [18], with evenness in the storage duration and conditions. Variables in the access cavity preparation were eliminated by the standardization of the remaining root length.

Artificial periodontal ligament simulation protocol was employed so that the stresses produced are distributed across the root surface rather than being concentrated in one particular area which can affect the fracture resistance [15, 19]. This setting has a greater clinical relevance as it mimics the support given to teeth by the supporting structures and results in less stress build-up caused by unrealistic bending movements [20].

Statistical analysis revealed that NeoSealer Flo sealer with SCT had a significantly higher fracture resistance value (418.64±26.32N) compared to lateral compaction technique. One possible explanation could be the wedging forces and stresses employed by the spreader during LCT [21], which resulted in decreased fracture resistance when LCT was used with either NeoSealer Flo (294.49±4.26N) or AH Plus sealer (268.43±5.59N) (Table 1).

In a study by Piskin *et al*. [22] evaluating the effect of spreader use on the fracture resistance of roots filled with LCT, spreaders larger than size 25 resulted in a significant decrease in fracture resistance of roots. It was found that the maximum force applied to roots occurred during lateral condensation when being compared with Obtura and Thermafill techniques [23]. According to Ersoy and Evcil [22], LCT and Obtura technique did not increase the fracture resistance of the teeth due to the forces created by the use of spreaders and pluggers.

In the current study, roots obturated with NeoSealer Flo sealer using SCT showed significantly higher fracture resistance (418±26.32N) than roots obturated with AH Plus sealer using the same obturation technique (385.58±10.38N). This result was in accordance with Hedge and Arora [25], who reported that canals obturated using SCT, Gutta-percha/EndoSequence sealer (Brasseler USA, Savannah, GA) had a higher fracture resistance compared to gutta-percha/AH Plus. One major advantage of using SCT is that it creates a homogenous mass when combined with endodontic sealers avoiding failures seen among multiple cones as in LCT [26].

Irrespectively to the obturation technique used, the mean fracture resistance with NeoSealer Flo BC sealer was higher compared to AH Plus sealer (Figure 1). This result came in accordance with Patil *et al* [27], where the EndoSequence bioceramic sealer, exhibited significant results in reinforcing the root samples compared to resin-based and calcium hydroxide-based sealers.

This result could be attributed to the hydrophilic nature of the bioceramic sealer with delayed setting time, allowing hydration and swelling to fill any voids. The reaction of phosphate from dentinal fluids with calcium silicate hydrogel and calcium hydroxide, produced through the reaction of calcium silicates in the presence of the dentine's moisture, resulting in the formation of hydroxyapatite. These by-products allow chemical bonding to the root canal dentine walls, improving sealer-to-root dentine bonding which increases the fracture resistance of teeth [28].

While bioceramic sealers have been available in the market and are frequently used, few studies have measured their clinical effectiveness to date combined with SCT. In a retrospective study, EndoSequence BC Sealer using a SCT achieved a success rate of 90.9% [29], while a recent non-randomized clinical trial revealed that a calcium silicate cement (BioRootTM RCS, Septodont, Saint-Maur-des Fosses, France), when used in SCT, resulted in a comparable percentage of successful cases when evaluated using cone-beam computed tomography after one year follow up period compared to warm vertical condensation and AH Plus sealer [30].

On the other hand, results showed that there was significant difference in values of fracture resistance of roots obturated with LCT using either sealer. This came in disagreement with Dibaji *et al* [31], where they found no statistically significant difference between root canals filled using LCT with gutta-percha/AH Plus sealer and gutta-percha/iRoot bioceramic sealer. AH Plus resin sealer with its creeping property and long polymerization period allow penetration into the micro-irregularities along the intraradicular dentine, which provide a mechanical interlocking mechanism between the sealer and root dentine [32,33].

Properties of hydraulic cements check many of the boxes of the ideal requirements of endodontic sealers. In-vitro studies have confirmed the lack of shrinkage on setting, bacteriostasis properties, insolubility in tissue fluids, and biocompatibility [34,35,36]. They have been shown to produce hydroxyapatite on setting and bonding with dentine within the canal [32]. These characteristics may allow the transition of obturation techniques from a gutta-percha-based technique into a sealer-based technique, which might end the stigma related to the use of SCT [37].

CONCLUSIONS

The use of bioceramic sealer with single cone technique has been shown to increase the fracture resistance of roots.

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