DOI: 10.7860/JCDR/2023/64663.18586

Original Article

Dentistry Section

Evaluation of the Fracture Resistance Offered by Three Different Intraorifice Barriers on Obturated Teeth: An In-vitro Study

SONAM MANGAONKAR[1], FEDERICO FOSCHI[2], KRISTLEE SABRIN FERNANDES[3], PAUL CHALAKKAL[4], NILESH KADAM[5], RAJAN LAMBOR[6]

ABSTRACT

Introduction: The mere placement of a restoration after obturation carries the risk of the presence of voids between them. These voids reduce overall strength and allow for leakage. The placement of Intraorifice Barriers (IOB) between the restoration and the obturated material has been known to have several advantages, including the prevention of microleakage, enhancement of strength, and improvement in Fracture Resistance (FR).

Aim: To evaluate if, Smart Dentin Replacement (SDR) flow plus, Resin Modified Glass Ionomer Cement (RMGIC), and Biodentine increase the FR of Endodontically Treated Teeth (ETT) as IOB. Additionally, the study aimed to compare the FR between roots sealed using Endosequence and AH Plus sealers.

Materials and Methods: This in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics, Goa Dental College and Hospital, Bambolim, Goa, India over a period of four weeks, from October 2020 to November 2020. The study sample consisted of 160 mandibular premolar roots instrumented using ProTaper gold rotary files. These roots were obturated with Gutta Percha (GP) and divided into two groups based on the sealer used (Group I=Endosequence; Group II=AH Plus). Each group was further divided into four subgroups, including a control group, with each subgroup receiving an IOB. FR was tested using a universal testing machine, and the forces were statistically analysed using Two-way Analysis of Variance (ANOVA), One-way ANOVA, and posthoc Bonferroni tests.

Results: SDR offered the greatest FR values of 583.08 N and 612.13 N in groups I and II, respectively. Roots sealed with AH Plus showed greater FR than those sealed with Endosequence. In both groups, the differences between IOB and the control group in terms of FR were found to be highly significant ($p<0.001$).

Conclusion: SDR showed the greatest FR when compared with RMGIC and BD as IOB in ETT. Teeth restored with SDR and sealed with AH Plus offered the greatest FR.

Keywords: Dental materials, Flexural strength, Non vital, Tooth

INTRODUCTION

Vertical Root Fracture (VRF) is defined as a crack in the tooth that extends longitudinally down the long axis of the root. It may extend from the root canal to the external surface [1]. Endodontically Treated Teeth (ETT) are the most common cause of VRF [2]. The placement of an Intraorifice Barrier (IOB) improves the coronal seal of the root canals, significantly reducing microleakage and increasing strength in ETT [3]. SDR Flow Plus (SDR; Dentsply, Sirona, Germany) is a low-viscosity flowable composite with a filler loading of 68 weight%, which allows it to access deep areas and decrease the formation of air bubbles [4,5]. However, no study has been conducted yet to evaluate the efficacy of SDR as an IOB. RMGIC (RMGIC; GC Fuji II LC Capsule, GC Corporation, Tokyo, Japan) chemically bonds with dentin, reinforcing the dentin-cement interface [6-8]. Biodentine (BD; Septodont, Saint Maur des Fossés, France) is a fast-setting, biocompatible, and bioactive material. BD has also been tested for its effects as an IOB in two previous studies [9,10].

Endosequence® BC® sealer (ES; Brasseler USA, Savannah, GA, USA) is a recent bioceramic sealer composed of calcium phosphate, calcium silicate, calcium hydroxide, zirconium oxide, fillers, and thickening agents [11]. It is a radiopaque, insoluble, and aluminum-free material [12]. Its biocompatibility and highly alkaline pH make it antibacterial during its setting reaction [13,14]. AH Plus® sealer (AHP; Dentsply, Konstanz, Germany) is a resilient epoxy resin-based sealer with superior radicular dentin bond strength and dentinal tubular penetration, compared with zinc-oxide eugenol, glass ionomer, or calcium hydroxide-based sealers [15,16].

A study comparing the Fracture Resistance (FR) of the aforementioned IOBs has not been carried out previously in the literature. Therefore, the aims of this study were to evaluate if SDR, RMGIC, and BD could increase the FR of ETT as IOBs, to compare the FR offered by the three IOBs on ETT, and to compare the FR between roots obturated using ES and AHP. The null hypotheses considered were that IOBs do not contribute to the FR of ETT, there are no differences between the FR offered by the three IOBs, and there are no differences between the FR offered by the two sealers.

This study highlights the role played by the three IOBs in resisting fractures, thus preventing them. The results would encourage dental practitioners to use IOBs for ETT in their practice, so that patients benefit from the long-term success of ETT by minimising fracture-related tooth loss.

MATERIALS AND METHODS

This in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics, Goa Dental College and Hospital, Bambolim, Goa, India over a period of four weeks, from October 2020 to November 2020. Institutional Ethical Clearance was obtained before commencing the study (Approval no: MRSU19/20-17231).

Inclusion and Exclusion criteria: A convenience sampling technique was used, where mandibular premolars with straight mature roots and single canals, extracted for orthodontic purposes, were selected for the present study. Teeth with carious, cracked (observed under a stereomicroscope), curved, thin, or short roots were excluded. Debris, calculus, and soft tissues were removed from the tooth surfaces.

Sample size calculation: The sample size was calculated using G*Power 3.1.9.7 software. The effect size was calculated based on parameters from a study by Nagas E et al., [17]. The derived sample size was 152 (19 per subgroup with a power of 0.9). However, to compensate for discarded samples due to dimensional irregularities, the final sample size was considered to be 160.

Study Procedure

All teeth were decoronated at a level 14 mm coronal from their apices using a diamond disc with copious water irrigation [Table/Fig-1]. The mesiodistal and buccolingual diameters at the coronal end of the samples were measured with a digital calliper, and the mean value was obtained. Roots whose diameters differed from the mean by 10% were discarded.

[Table/Fig-1]: Mandibular premolars decoronated at a level that was 14 mm coronal from their apices.

Biomechanical preparation of the samples: Working length determination was done by inserting a #10 K-file (Dentsply Maillefer, Tulsa, Okla.) into each tooth until it was observed at the apical foramen, followed by decreasing the file length by 1 mm. The canals were then instrumented using F3 ProTaper gold rotary files (Dentsply, Tulsa, OK) with a torque-controlled motor (TriAuto Mini; J Morita) according to the manufacturer's instructions. Irrigation was performed using 2.5% Sodium Hypochlorite (NaOCl) and 17% Ethylenediaminetetraacetic Acid (EDTA) (Dent Wash; Prime Dental Products Pvt., Ltd.). Cleaning and shaping were carried out using shaping files SX, S1, and S2, and finishing files F1, F2, and F3, following the standard procedure utilising 17% EDTA (Glyde, Dentsply, Tulsa). The canals received a final irrigation of 5 mL of 17% EDTA and 5 mL of 2.5% NaOCl for two minutes each, after which the canals were flushed with 10 mL of distilled water. The canals were then dried using F3 ProTaper Paper points (Dentsply).

Classification into groups based on the sealer type: The random sampling method was used to assign the premolars into two groups (n=80/group) depending on the type of sealer to be used with GP:

Group-I: GP with ES

Group-II: GP with AHP

Obturation was carried out using F3 ProTaper single GP cone (Dentsply) along with the sealer, following the manufacturer's instructions.

Classification into subgroups based on the type of IOB: The coronal portion of all the samples was removed to a depth of 3 mm using Gates Glidden burs (JS Dental Pvt., Ltd., Switzerland). The random sampling method was used to allocate samples from each group into four subgroups based on the type of IOB they were to be restored with, to a thickness of 3 mm, following the manufacturer's instructions (n=20/subgroup):

Subgroup-A: SDR (n=20)

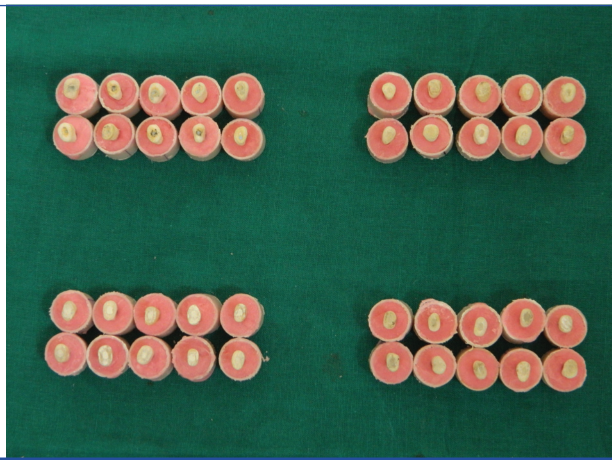
Subgroup-B: RMGIC (n=20)

Subgroup-C: BD (n=20)

Subgroup-D: Control/No orifice barrier (n=20)

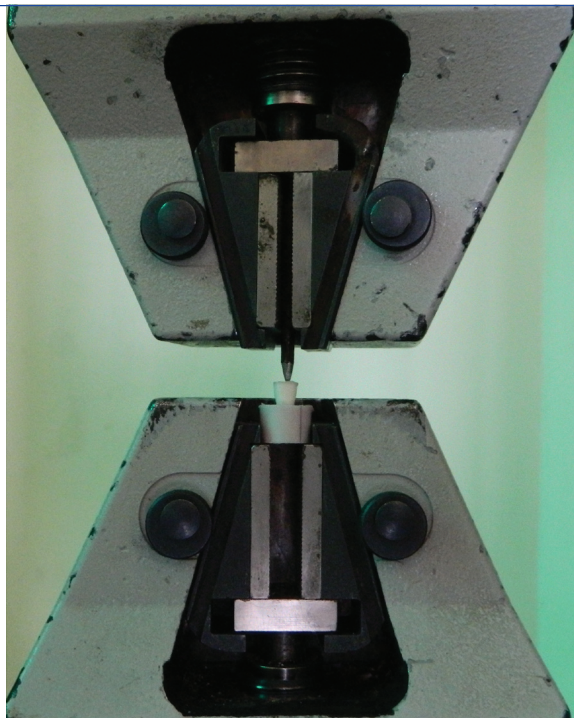
After restoration of the samples with IOB according to the subgroups, they were stored at 37°C and 100% humidity for two weeks for complete setting.

Preparation for mechanical testing: The roots were embedded in a 12 mm thickness of acrylic resin (DPI; RR cold cure) in a Polyvinyl Chloride (PVC) ring, so that 9 mm of the coronal section of each root was exposed [Table/Fig-2]. An orthodontic wire (30 gauge) was bent into a square "J" shape. The short handle of the "J" was looped around the canal orifice of each root, while the long handle was attached to the outer surface of the PVC ring. This allowed for the suspension of the tooth in the center of the ring, parallel to the long axis of the root [18].



[Table/Fig-2]: Roots embedded in 12 mm thickness of acrylic resin in a Polyvinyl Chloride (PVC) ring.

The mounted tooth was then placed on the Universal Testing Machine (UTM; Lloyd, LR-50, UK) for mechanical testing. A custom-made stainless-steel rod with a 2 mm spherical tip was attached to the upper stage. The tip of the rod was centered over the access opening of each root, until the tip of the rod just contacted the circumference of the opening of the root [Table/Fig-3]. A downward force was applied at a speed of 1 mm/min until fracture of the root occurred. Fracture was defined as the point at which a sudden drop, greater than 25 percent of the applied load, was observed [19]. The force (Newtons/N) at this point was measured and recorded. A single operator carried out all the above procedures to avoid bias.



[Table/Fig-3]: Mounted tooth was placed on the universal testing machine for mechanical testing.

STATISTICAL ANALYSIS

Mean, standard deviation, standard error, and 95% confidence interval were obtained for the recorded forces. These values were then subjected to statistical analysis (two-way ANOVA, one-way ANOVA, and posthoc Bonferroni tests) using G*Power 3.1.9.7 software. The level of significance was considered to be p<0.05.

RESULTS

The mean, standard deviation, standard error, and 95% confidence interval values of FR in both groups restored with the three IOB. Among the IOB has been illustrated in [Table/Fig-4], the roots restored with SDR showed the highest mean FR values of 583.08 N and 612.13 N in Group-1 and Group-2, respectively. However, those restored with RMGIC showed the lowest mean FR value of 523.29 N in Group-1, and those restored with BD showed the lowest mean FR value of 556.30 N in Group-2 [Table/Fig-4].

into dentinal tubules and irregularities increases the FR of ETT [1,22]. The hydrophilic nature of the sealer enables it to absorb moisture from the dentin tubules to facilitate its setting process [22]. If the available moisture is insufficient, the setting reaction of the sealer could be affected [23]. However, shrinkage of the sealer has not been found to occur upon setting [22].

AHP has low solubility, a large film thickness, creep capacity, and a long polymerisation process. These properties improve the mechanical interlocking between the sealer and radicular dentin [24]. However, there is no chemical bond between GP and AHP [19]. Therefore, a monoblock system is never obtained [25]. The FR contributed by AHP is due to the covalent bond formed between open epoxide rings and the amino groups in collagen [26], low setting shrinkage, and long-term dimensional stability [27]. There have been only two studies in the literature that have compared ES and AHP with regard to FR of ETT. Patil P et al., found that ETT

Group	Orifice barrier	N	Mean	Standard deviation	Standard error	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
Group-1	SDR	20	583.0850	148.08410	33.11261	513.7795	652.3905	361.20	881.20
	RMGIC	20	523.2900	122.33187	27.35424	466.0369	580.5431	276.60	755.50
	BD	20	532.3850	82.33395	18.41043	493.8515	570.9185	345.60	697.70
	Control	20	320.5050	61.41893	13.73369	291.7601	349.2499	198.50	412.20
	Total	80	489.8162	147.01317	16.43657	457.1001	522.5324	198.50	881.20
Group-2	SDR	20	612.1300	106.60511	23.83763	562.2373	662.0227	434.80	820.00
	RMGIC	20	582.9900	92.47682	20.67845	539.7095	626.2705	376.80	767.00
	BD	20	556.3050	99.16812	22.17466	509.8929	602.7171	345.60	765.10
	Control	20	345.9300	70.68423	15.80547	312.8488	379.0112	167.40	466.70
	Total	80	524.3388	139.62755	15.61084	493.2662	555.4113	167.40	820.00

[Table/Fig-4]: Descriptive table showing the fracture resistance of roots in both groups restored with various orifice barriers.

There was a significant difference (p<0.05) between the two groups regarding FR. The roots sealed with AHP showed higher FR than those sealed with ES [Table/Fig-5]. However, the combined effects (interactive differences) between the groups and the subgroups were not found to be statistically significant (p=0.841; [Table/Fig-5]).

Source	Type-III sum of squares	df	Mean square	F-value	p-value
Model	4.287×107	8	5359252.699	521.630	<0.00001
Group	47672.120	1	47672.120	4.640	0.033*
Orifice barrier	1677344.039	3	559114.680	54.420	<0.0001**
Group×barrier	8590.870	3	2863.623	0.279	0.841
Error	1561654.390	152	10274.042		
Total	4.444×107	160			

[Table/Fig-5]: Two-way ANOVA.
R Squared=0.965 (Adjusted R Squared=0.963); *p<0.05; Significant; **p<0.001; Highly significant

Group	Comparison	Mean difference	p-value	Significance
Group-1	SDR vs RMGIC	59.795	0.519	Not significant
	SDR vs BD	50.700	0.871	Not significant
	SDR vs Control	262.580	<0.001	Highly significant
	RMGIC vs BD	9.095	1.000	Not significant
	RMGIC vs Control	202.785	<0.001	Highly significant
	BD vs Control	211.880	<0.001	Highly significant
Group-2	SDR vs RMGIC	29.140	1.000	Not significant
	SDR vs BD	55.825	0.372	Not significant
	SDR vs Control	266.200	<0.001	Highly significant
	RMGIC vs BD	26.685	1.000	Not significant
	RMGIC vs Control	237.060	<0.001	Highly significant
	BD vs Control	210.375	<0.001	Highly significant

[Table/Fig-6]: One-way ANOVA with posthoc Bonferroni test.

In both groups, the differences between IOB and the control, regarding FR, were highly significant (p<0.001) [Table/Fig-6]. No significant differences were observed between the two groups when comparing the FR of each IOB in both groups [Table/Fig-7]. Therefore, the null hypotheses were rejected.

Cement	Group-1	Group-2	p-value
	Mean±SD	Mean±SD	
SDR	583.09±148.08	612.13±106.61	0.481; NS
RMGIC	523.29±122.33	582.99±92.48	0.090; NS
BD	532.39±82.33	556.31±99.17	0.412; NS
Control	320.51±51.42	345.93±70.68	0.232; NS

[Table/Fig-7]: Comparison between the mean fracture resistances of the roots between groups I and II for each of the orifice barriers.
p>0.05; NS: Not significant

DISCUSSION

Endodontic treatment makes the tooth vulnerable to fracture due to the loss of structure. However, the right choice of sealant and IOB may help reduce this risk. Dentin loss, obturational forces, dentinal exposure to irrigants and dehydration weaken the dentin and increase its vulnerability to VRF [20]. VRF accounts for 11-13% of all extracted ETT [21]. In the present, roots sealed with AHP showed higher FR than those with ES, but the difference was not statistically significant. ES chemically bonds to radicular dentin through the formation of hydroxyapatite crystals during the setting process [12]. Since the sealer is composed of nanoparticles, its penetration deep

incorporating ES offered better FR than those with AHP [1]. However, Topçuoğlu HS et al., found that ES and AHP were equally efficient in offering FR in ETT. Although they used AH Plus Jet sealer (Dentsply De Trey, Konstanz, Germany), which has the same components as AHP [12]. The results of this study contradict the findings of Patil P et al., and Topçuoğlu HS et al., as the roots sealed with AHP showed significantly greater FR than those with ES (p<0.05) [1,12].

SDR can be polymerised to a depth of 4 mm at once, which is about double the depth possible for polymerising conventional composites [28]. It also contains a modified methacrylate resin (polymerisation modulator) that slows down the polymerisation rate, reducing the stresses caused by polymerisation shrinkage [5,29]. There has been no previous study in which the FR of SDR as an IOB has been tested. Therefore, no comparisons could be made. However, in this study, SDR offered the greatest FR compared to RMGIC or BD in ETT that incorporated ES or AHP as sealers. However, no significant differences were found between the IOB with regard to FR. The superior FR of SDR as an IOB may be attributed to its excellent mechanical interlocking resulting from superior polymerisation depth and slow polymerisation rate.

RMGIC has superior flexural strength and modulus of elasticity (10-14 GPa), similar to that of dentin [30,31]. These properties help it withstand large amounts of stress [32,33]. The cement expands on setting due to water sorption, improving its sealing ability [31]. Like conventional glass ionomer cements, RMGIC also releases fluoride [34]. In studies comparing the FR offered by RMGIC, Fiber-Reinforced Composite (FRC), and Mineral Trioxide Aggregate (MTA) as IOB, RMGIC offered the greatest FR while MTA offered the least [17,35]. In studies that tested the FR offered by Nano Composites (NC) in addition to RMGIC, FRC, and MTA as IOB, it was found that RMGIC offered the greatest FR, followed by FRC, NC, and MTA [6]. Moreover, RMGIC and flowable composites were found to offer greater FR as IOB than bonded amalgam [30,36]. In a randomised clinical trial, primary teeth pulpectomies were carried out using glass ionomer cement as IOB for a period of 12 months, and no changes were observed in the periapical healing of apical periodontitis in those teeth [37]. There has not been any previous study that has compared the FR offered by SDR, RMGIC, and BD as IOB on ETT.

The powder of BD contains silicates, calcium carbonate, and oxides of calcium, iron, and zirconium. Its liquid contains an accelerator (calcium chloride) and a water-soluble polymer [10]. The small particle size of the components of BD enhances their penetration into dentinal tubules [38]. The ions of calcium and silicon that penetrate into dentinal tubules form structures resembling tags that function like anchors [39]. In a recent study by Yasa E et al., the FR offered by BD was inferior to that offered by a bulk fill flowable composite resin (Filtek Bulk Fill flowable; 3M Espe) [10]. This finding matches with that of this study, except for the brand of the bulk fill flowable composite resin used in this study (SDR).

Limitation(s)

The study included only healthy mandibular premolar teeth, thereby risking sampling and representative bias. However, the selection bias was addressed by randomly assigning the teeth to different subgroups. Although immense care was taken to standardise the quality, shape, and dimensions of the premolars, unobservable structural defects such as cracks and canal irregularities would have existed that could have affected force values.

CONCLUSION(S)

SDR showed the greatest FR when compared with RMGIC and BD as IOB in ETT. However, these differences were not statistically significant. The roots sealed with AHP showed greater FR than those with ES but were not statistically significant. Future research is suggested to compare newer IOB and root canal sealers with regard to microleakage and FR, on molar teeth.

REFERENCES

[1] Patil P, Banga KS, Pawar AM, Pimple S, Ganeshan R. Influence of root canal obturation using gutta-percha with three different sealers on root reinforcement of endodontically treated teeth. An in-vitro comparative study of mandibular incisors. J Conserv Dent. 2017;20(4):241-44.

[2] Tsesis I, Rosen E, Tamse A, Taschieri S, Kfir A. Diagnosis of vertical root fractures in endodontically treated teeth based on clinical and radiographic indices: A systematic review. J Endod. 2010;36(9):1455-58.

[3] de Araújo LP, da Rosa WL, de Araujo TS, Immich F, da Silva AF, Piva E. Effect of an intraorifice barrier on endodontically treated teeth: A systematic review and meta-analysis of in-vitro studies. BioMed Res Int. 2022;20:2789073.

[4] Kim EH, Jung KH, Son SA, Hur B, Kwon YH, Park JK. Effect of resin thickness on the microhardness and optical properties of bulk-fill resin composites. Restor Dent Endod. 2015;40(2):128-35.

[5] Moorthy A, Hogg CH, Dowling AH, Grufferty BF, Benetti AR, Fleming GJ. Cuspal deflection and microleakage in premolar teeth restored with bulk-fill flowable resin-based composite base materials. J Dent. 2012;40(6):500-05.

[6] Gupta A, Arora V, Jha P, Nikhil V, Bansal P. An in-vitro comparative evaluation of different intraorifice barriers on the fracture resistance of endodontically treated roots obturated with gutta-percha. J Conserv Dent. 2016;19(2):111-15.

[7] Nagas E, Cehreli ZC, Durmaz V, Vallittu PK, Lassila LV. Shear bond strength between a polyester-based root canal filling material and a methacrylate-based sealer with an intermediate layer of fiber-reinforced resin-based material. J Adhes Dent. 2009;11(4):325-30.

[8] Moberg M, Brewster J, Nicholson J, Roberts H. Physical property investigation of contemporary glass ionomer and resin-modified glass ionomer restorative materials. Clin Oral Investig. 2019;23(3):1295-308.

[9] Nagas E, Cehreli ZC, Uyanik O, Vallittu PK, Lassila LV. Reinforcing effect of glass fiber–incorporated ProRoot MTA and Biodentine as intraorifice barriers. J Endod. 2016;42(11):1673-76.

[10] Yasa E, Arslan H, Yasa B, Akcay M, Alsancak M, Hatirli H. The force required to fracture endodontically roots restored with various materials as intra-orifice barriers. Niger J Clin Pract. 2017;20(10):1237-41.

[11] Azimi S, Fazlyab M, Sadri D, Saghiri MA, Khosravanifard B, Asgary S. Comparison of pulp response to mineral trioxide aggregate and a bioceramic paste in partial pulpotomy of sound human premolars: A randomized controlled trial. Int Endod J. 2014;47(9):873-81.

[12] Topçuoğlu HS, Tuncay O, Karataş E, Arslan H, Yeter K. In-vitro fracture resistance of roots obturated with epoxy resin–based, mineral trioxide aggregate–based, and bioceramic root canal sealers. J Endod. 2013;39(12):1630-33.

[13] Loushine BA, Bryan TE, Looney SW, Gillen BM, Loushine RJ, Weller RN, et al. Setting properties and cytotoxicity evaluation of a premixed bioceramic root canal sealer. J Endod. 2011;37(5):673-77.

[14] Zhang H, Shen Y, Ruse ND, Haapasalo M. Antibacterial activity of endodontic sealers by modified direct contact test against Enterococcus faecalis. J Endod. 2009;35(7):1051-55.

[15] Mamootil K, Messer HH. Penetration of dentinal tubules by endodontic sealer cements in extracted teeth and in vivo. Int Endod J. 2007;40(11):873-81.

[16] Mandava J, Chang PC, Roopesh B, Faruddin MG, Anupreeta A, Uma C. Comparative evaluation of fracture resistance of root dentin to resin sealers and a MTA sealer: An in-vitro study. J Conserv Dent. 2014;17(1):53-56.

[17] Nagas E, Uyanik O, Altundasar E, Durmaz V, Cehreli ZC, Vallittu PK, et al. Effect of different intraorifice barriers on the fracture resistance of roots obturated with Resilon or gutta-percha. J Endod. 2010;36(6):1061-63.

[18] Johnson ME, Stewart GP, Nielsen CJ, Hatton JF. Evaluation of root reinforcement of endodontically treated teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2000;90(3):360-64.

[19] Teixeira FB, Teixeira EC, Thompson JY, Trope M. Fracture resistance of roots endodontically treated with a new resin filling material. J Am Dent Assoc. 2004;135(5):646-52.

[20] Haueisen H, Gärtner K, Kaiser L, Trohorsch D, Heidemann D. Vertical root fracture: Prevalence, etiology, and diagnosis. Quint Int. 2013;44(7):467-74.

[21] Vire DE. Failure of endodontically treated teeth: Classification and evaluation. J Endod. 1991;17(7):338-42.

[22] Hess D, Solomon E, Spears R, He J. Retreatability of a bioceramic root canal sealing material. J Endod. 2011;37(11):1547-49.

[23] Celikten B, Uzuntas CF, Gulsahi K. Resistance to fracture of dental roots obturated with different materials. Bio Med Res Int. 2015;2015:591031.

[24] Chadha R, Taneja S, Kumar M, Sharma M. An in-vitro comparative evaluation of fracture resistance of endodontically treated teeth obturated with different materials. Contemp Clin Dent. 2010;1(2):70-72.

[25] Aptekar A, Ginnan K. Comparative analysis of microleakage and seal for 2 obturation materials: Resilon/epiphany and gutta-percha. J Can Dent Assoc. 2006;72(3):245.

[26] Fisher MA, Berzins DW, Bahcall JK. An in-vitro comparison of bond strength of various obturation materials to root canal dentin using a push-out test design. J Endod. 2007;33(7):856-58.

[27] Nagas E, Uyanik MO, Eymirli A, Cehreli ZC, Vallittu PK, Lassila LV, et al. Dentin moisture conditions affect the adhesion of root canal sealers. J Endod. 2012;38:240-44.

[28] Rayyan MM. Comprehensive techniques for intra-radicular rehabilitation of weakened anterior teeth. Egypt Dent J. 2014;60:1289-97.

[29] Van Ende A, De Munck J, Van Landuyt KL, Poitevin A, Peumans M, Van Meerbeek B. Bulk-filling of high C-factor posterior cavities: Effect on adhesion to cavity-bottom dentin. Dent Mater. 2013;29(3):269-77.

[30] Goldberg F, Kaplan A, Roitman M, Manfré S, Picca M. Reinforcing effect of a resin glass ionomer in the restoration of immature roots in-vitro. Dent Traumatol. 2002;18(2):70-72.

[31] Xie D, Brantley WA, Culbertson BM, Wang G. Mechanical properties and microstructures of glass-ionomer cements. Dent Mater. 2000;16(2):129-38.

[32] Trope M, Ray HL Jr. Resistance to fracture of endodontically treated roots. Oral Surg Oral Med Oral Pathol. 1992;73(1):99-102.

[33] Kwon OH, Park SH. Evaluation of internal adaptation of dental adhesive restorations using micro-CT. Restor Dent Endod. 2012;37(1):41-49.

[34] Yavari H, Samiei M, Eskandarinezhad M, Shahi S, Aghazadeh M, Pasvey Y. An in-vitro comparison of coronal microleakage of three orifice barriers filling materials. Iran Endod J. 2012;7(3):156-60.
[35] Sathorn C, Palamara JE, Palamara D, Messer HH. Effect of root canal size and external root surface morphology on fracture susceptibility and pattern: A finite element analysis. J Endod. 2005;31(4):288-92.
[36] Aboobaker S, Nair BG, Gopal R, Jituri S, Veetil FR. Effect of intra-orifice barriers on the fracture resistance of endodontically treated teeth- an ex-vivo study. J Clin Diagn Res. 2015;9(2):ZC17-20.
[37] Kumar G, Tewari S, Sangwan P, Tewari S, Duhan J, Mittal S. The effect of an intraorifice barrier and base under coronal restorations on the healing of apical periodontitis: A randomized controlled trial. Int Endod J. 2020;53(3):298-307.
[38] Guneser MB, Akbulut MB, Eldeniz AU. Effect of various endodontic irrigants on the push-out bond strength of biodentine and conventional root perforation repair materials. J Endod. 2013;39(3):380-84.
[39] Han L, Okiji T. Uptake of calcium and silicon released from calcium silicate-based endodontic materials into root canal dentine. Int Endod J. 2011;44(12):1081-87.

PARTICULARS OF CONTRIBUTORS:
1. Associate Dentist, Citident Dental Practice, 13-15 Yearlstone Square, Ashland, Milton Keynes, MK6 4AT, United Kingdom.
2. Clinical Senior Lecturer and Consultant, Department of Oral and Craniofacial Sciences, King's College London, London, United Kingdom.
3. Associate Dentist, Deddington Dental, Oxfordshire, United Kingdom.
4. Assistant Professor, Department of Pedodontics and Preventive Dentistry, Goa Dental College and Hospital, Bambolim, Goa, India.
5. Principal Dentist, Kadam's Family Dental Care, Virar, Maharashtra, India.
6. Professor, Department of Conservative Dentistry and Endodontics, Goa Dental College and Hospital, Bambolim, Goa, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Paul Chalakkal,
Assistant Professor, Department of Pedodontics and Preventive Dentistry,
Goa Dental College and Hospital, Bambolim-403202, Goa, India.
E-mail: atomheartpaul@yahoo.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Apr 13, 2023
- Manual Googling: Jul 18, 2023
- iThenticate Software: Jul 25, 2023 (12%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Apr 12, 2023**
Date of Peer Review: **Jul 04, 2023**
Date of Acceptance: **Jul 28, 2023**
Date of Publishing: **Oct 01, 2023**