Original Article International Journal of Dental Materials 2022;4(2) ISSN:2582-2209

Evaluation of effect of core build-up materials on fracture resistance of endodontically treated teeth

Vijay Linju[1], V.P Prabath Singh[2,*], Hariharan Madhu[3], Presannakumar Gayathri[1]

[1]Postgraduate Student, [2]Professor, [3]Reader, Department of Conservative Dentistry and Endodontics, Amrita School of Dentistry, Amrita Vishwa Vidyapeetham, Kochi, Kerala, India.

Article History

Received 18th *January 2022*

Received revised 21st *February* 2022

Accepted 3rd *March 2022*

Available online *22nd April 2022*

*Correspondence

Prabath Singh V.P.

Professor,

Department of Conservative Dentistry and Endodontics, Amrita School of Dentistry,

Amrita Vishwa Vidyapeetham, Kochi, Kerala, India.

E-mail: drprabathendo@gmail.com

DOI: http://dx.doi.org/10.37983/IJDM.2022.4203

Abstract

Background: Restoration of teeth after endodontic treatment is becoming an integral part of reconstructive dentistry.

Aim: The aim of this study was to evaluate the effect of different core build-up materials on fracture resistance of endodontically treated teeth.

Materials and methods: Freshly extracted forty permanent mandibular first molars were selected. Standardized access cavities were prepared, following which mesial canals were prepared up to F2 (8%25) and distal canals up to F3 (9%30) and obturated. The coronal portion of the specimen was altered by removing the mesial wall and retaining buccal, lingual and mesial walls of 2mm and distal 5mm girth. Ten specimens each were rehabilitated with high copper amalgam, type IX GIC, posterior composite and Alkasite as core build-ups. All the specimens were finally rehabilitated with a metal crown. The specimens were tested for fracture resistance using a universal testing machine under oblique (135° to the long axis of teeth) cyclic loading. The number of cycles taken to fracture, and the fracture site was recorded. The results of mechanical cyclic loading to evaluate fracture resistance showed that composite core endured the maximum number of cycles to fracture followed by amalgam, Alkasite and type IX GIC.

To test the statistical significance in the difference of mean value K_{IC} among four groups, Kruskal-Wallis one-way analysis of variance was applied. Bonferroni's multiple comparison test was performed to determine which group significantly differed from the others.

Results: From the results of this study, the composite was considered to be the best core build-up material. The newer material, Alkasite can bear stress almost to that of amalgam restoration.

Conclusion: This study suggests that Alkasite could be used as a core material for restoring the endodontically treated teeth.

Keywords: Endodontically treated teeth, Alkasite, Cyclic loading.

1. Introduction

Restoration of teeth after endodontic treatment is becoming an integral part of reconstructive dentistry. Endodontically treated teeth are more susceptible to fracture than vital teeth because of excessive loss of tooth tissue, dehydration of the dentin, and pressure during obturation procedures [1].

The core build-up is one of the most important steps to restore a severely damaged, fractured or extensively carious tooth. As the core becomes an integral part of the load-bearing structure of the tooth, it should provide resistance and retention form for the coronal restoration and possess sufficient strength to resist occlusal forces [2]. An ideal core build-up material should have physical properties similar to that of tooth structure. Since a restored tooth tends to transfer stress differently than an intact tooth where the occlusal masticatory loads are transferred to dentin as compression that is distributed over a large internal volume of tooth structure thereby reducing local stress [3].

Amalgam, composite resin, and glass-ionomer materials have been used as core build-up materials. Alkasite is a tooth-coloured, and basic filling material for bulk placement in retentive preparations. It consists of an isofiller composed of cured dimethacrylates, glass filler and ytterbium fluoride that acts as a shrinkage stress reliever. The Isofiller is a patented filler functionalized by silanes and is bonded to other filler particles. This enhances the bond between the organic monomer matrix and the inorganic filler. Photoinitiators, Ivocerin – a dibenzoyl germanium derivative and acyl phosphine oxide absorb photons during curing leading to cleavage of chemical bond within the initiators leading to the formation of two radicals which react with the organic monomers to produce a strong polymer network. These fillers are responsible for imparting adequate strength [4].

Core build-up materials are used to complement a technically sound endodontic treatment and therefore need to possess sufficient strength to resist the applied stresses [5]. The aim of this study was to evaluate the effect of different core build-up materials on fracture resistance of endodontically treated teeth.

2. Materials and methods

Forty caries-free extracted human mandibular molars (extracted for periodontal reasons) with completed apexification from the mixed population were selected with the following inclusion criteria [19]. Intact mandibular first molars with normal anatomy, without root canal calcifications or sclerosis and normal root curvatures, were included. Those severely dehydrated or fractured, significant caries or restorations, dilacerated roots and resorption were excluded.

The selection of specimens was based on the teeth having a root length between 10 and 12mm and similar bucco-lingual (BL) and mesio-distal (MD) dimensions, as determined with a digital calliper (Mitutoyo, Tokyo, Japan), allowing a maximum of 10% deviation from the average. An ultrasonic scaler (Dentsply, Germany; Piezon Systems, EMS, Switzerland) was used to remove soft tissues, calculus and debris from the teeth before examination under a dental operating microscope (G3, Global Surgical Corporation) for detection of any cracks or fractures [20].

The teeth were stored individually in buffered saline plus 0.5% thymol (Explicit Chemicals Pvt Ltd) at 37°C. The teeth were subjected to radiographic examination, and the specimens that did not meet the criteria were replaced. The specimens were randomly assigned to 4 experimental groups (n= 10).

2.1 Specimen preparation

Endodontic access was performed with a round diamond rotary cutting instrument (18163 Great white Z; SS White, Lakewood, NJ) and the root canal patency was confirmed with a number 10 K-file (Dentsply M-Access Kfile 21mm #010, Dentsply Maillefer, North America).Chemo mechanical preparation was performed with rotary files (Protaper Universal System; Dentsply Maillefer, Switzerland) and rotary instrumentation (X- Smart plus Endodontic Rotary Motor; Dentsply Maillefer, North America) up to F2(8%25) file in mesial canals and F3 (9%30)in distal canal 0.5 mm from the apex. 5% Sodium hypochlorite (Vensons India, Bengaluru) and EDTA irrigation (RC Help; Prime Dental Pvt Ltd, Thane, Maharashtra) was done. The root canal was dried with paper points and obturated by lateral condensation with resin cement (AH Plus; Dentsply Maillefer-USA) and corresponding gutta-percha points (Protaper universal gutta-percha points; Dentsply Maillefer-North America).

The coronal portion of the specimen was altered by removing the mesial wall with a round carbide bur (Tri hawk, Part No. 8, Head Diameter (2.3mm), Head Length (2.3mm)) leaving only buccal and lingual walls of 2mm girth, Distal wall with 4-5 mm thickness (Figure 1) and was confirmed with digital calipers.

The 40 specimens were divided into four groups receiving four different core build-up materials as post endodontic restorations (Figure 2).
Group A: High copper amalgam (DPI alloy fine grain & Mercury; Dental products of India, Mumbai).
Group B: Type IX- glass ionomer cement (GC India Dental Pvt. Ltd).
Group C: Composite (Ceram X, Dentsply India Pvt. Ltd).
Group D: Alkasite (Cention N, Ivoclar Vivadent,Schaan,Liechtenstein).

All specimens were prepared for full a metal crown with a tapered rounded-end diamond rotary cutting instrument (no. 4138; KG Sorensen) in a high-speed handpiece with air-water spray (NSK Pana Max; Japan)). Teeth were prepared with 1 mm of axial reduction and 6° of axial convergence, 0.5 mm wide chamfer margin and the cervicoincisal height remained at 8.0 mm for all specimens. Impressions of the specimens were made using addition silicone impression material (Aquasil; Dentsply Caulk, Milford, DE). Then the impressions were poured with type IV stone (Durone IV; Dentsply, Brazil). All specimens were restored with metal crowns (Dentcare Dental Labs, India).

The roots were wrapped with a single layer of aluminium foil and mounted 45° to the base of 3x3 cm epoxy resin (Environmental Technology, Inc, Fields Landing, USA) cubes (figure 3). All teeth were embedded 2 mm apical to the CEJ in epoxy resin to simulate natural bone level. The foil was removed, and the space left behind between the tooth and resin was replaced with addition silicone light body elastomeric impression material (Aquasil; Dentsply Caulk, Milford, DE) simulating the periodontal ligament.

2.2 Mechanical cyclic loading procedure

The specimens were loaded in a cyclic loading machine with a load cell unit capacity of 5000N (Mecmesin Universal Testing machine; West Sussex, UK) subjected to 0-800 N cycles at a crosshead speed of 0.5mm/min and pyramidal-shaped intender with contact surface area 2x2mm^2. The machine employs workshop and data manager software to analyse the measured data and plot the graphs.

The specimens were secured using grippers, and 10 specimens from each group were subjected to oblique loading at 135° to the long axis of the root (Figure 4). Fracture was defined as a point at which a sharp and instantaneous drop or deflection in the graph is noticed (Figure 5). Maximum fracture loads were recorded for analysis. Based on the mean and standard deviation of K_{IC} value, in the three groups of comparison observed in previous publications and with more than 90% power and 99% confidence minimum sample size required in each group counts to ten. To test the statistical significance of the difference of mean value K_{IC} among four groups, Kruskal-Wallis one-way analysis of variance was applied. When Kruskal-Wallis one-way analysis indicated significant results, Bonferroni's multiple comparison test was performed to determine which group significantly differed from the others.

3. Results

3.1 Evaluation of fracture resistance and mode of failure under mechanical cyclic loading

To evaluate the effect of oblique cyclic loading on the fracture resistance, 10 specimens from each group were statistically analyzed using the Kruskal-Wallis test and the results are summarized in Table 1.

In composite groups, the mean number of cycles was 151850 with a standard deviation (SD) of 9055.54, among Amalgam group was 106100 with SD of 4830.23, among Alkasite group was 93260.00 with SD of 3070.36 and among GIC group was 78470.00 with SD of 5649.00. It was statistically significant ($p<0.001$).

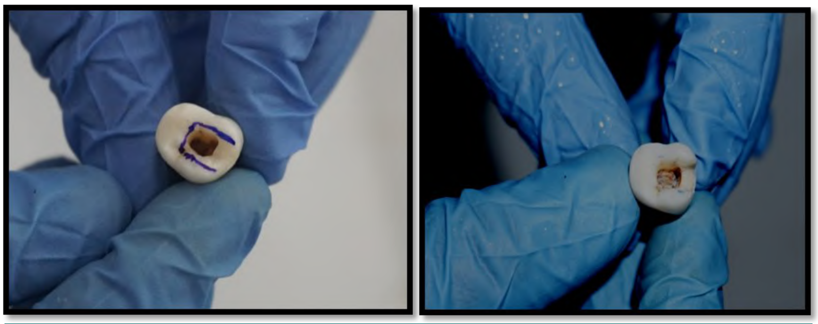

Figure 1. 2mm remaining axial wall thickness

Figure 2. Core build-up

Figure 3. Specimens rehabilitated with full metal crown

Figure 4. Application of oblique cyclic loading on the specimens

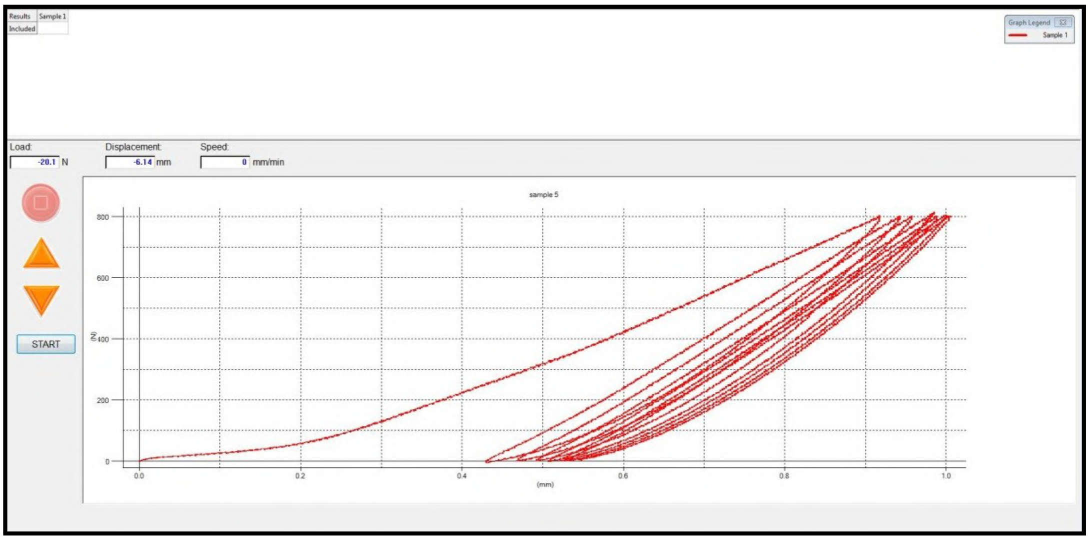

Figure 5. Graph showing no. of cycles until fracture generated in computer software

Since the Kruskal-Wallis test indicated a significant difference ($p<0.001$), multiple comparisons were performed using Bonferroni's test to determine which group significantly differed from the others. The analysis showed significant differences ($p<0.001$) between other groups. The results are filtered to display only the statistically significant pairs in Table 2. As the number of cycle values among groups was statistically significant, pairwise comparison was done which showed that mean number of cycle values between Composite to Amalgam ($p<0.001$), Composite to Alkasite ($p<0.001$), Composite to GIC ($p<0.001$), Amalgam to Alkasite ($p<0.001$), Amalgam to GIC ($p<0.001$) and Alkasite to GIC ($p<0.001$) were statistically significant. While assessing the site of fractures, all specimens showed a fracture at the cervical region and were non-repairable failures, including crown and root fractures, at or below the level of bone simulation.

4. Discussion

The material selection for restoration of endodontically treated teeth is a challenging task that usually involves the treatment of teeth with significant loss of tooth structure. The remaining coronal portion of the tooth plays a crucial role in the type of core materials to be used, while its position decides the choice of the prosthetic phase of the final restoration. Multiple in vitro studies have shown that even the best root canal treatment can allow leakage of bacteria and their by-products through a well-filled canal system [6]. According to Ray and Trope, [7] the coronal restoration had a significant impact on the success than the quality of root canal treatment.

Table 1. Mean comparison of number of cycles among groups				
Groups	n	Number of Cycles		p Value
		Mean	SD	
Composite	10	151850.00	9055.54	<0.001
Amalgam	10	106100.00	4830.23	
Alkasite	10	93260.00	3070.36	
GIC	10	78470.00	5649.00	

Table 2. Pairwise comparison among groups				
Groups		Mean Difference	Std. Error	p Value
Composite	Amalgam	45750.00	2708.06	<0.001
	Alkasite	58590.00	2708.06	<0.001
	GIC	73380.00	2708.06	<0.001
Amalgam	Alkasite	12840.00	2708.06	<0.001
	GIC	27630.00	2708.06	<0.001
Alkasite	GIC	14790.00	2708.06	<0.001

The endodontically treated tooth (ETT) are known to have a higher risk of biomechanical failure than vital teeth. The greatest concern clinically is the irreversible failure with root fracture necessitating extraction of the tooth.

Extracted human first mandibular molars, with similar mesiodistal and buccolingual widths as well as root length, were selected for the study for the following reason. Mandibular first molar is amongst the earliest permanent teeth to erupt in the oral cavity and hence is more prone to most of the biomechanical changes. Also, these teeth are subjected to most of the masticatory load. According to Rosenstiel, posterior teeth are subjected to greater occlusal loads than anterior teeth because they are closer to the fulcrum of the jaw (the temporomandibular joint). Similarly, the morphology that characterizes posterior teeth (a divided occlusal surface with cusps that can be wedged apart) makes them susceptible to fracture, especially during excursive movements when working and/or balancing interferences are present [8].

Teeth that had recently been extracted and stored in an appropriate medium were chosen for mechanical fracture testing to avoid dehydration-related changes in mechanical and physical properties [9]. For standardization, the teeth were collected from a mixed population, with dimensions as equal as possible to minimize the influence of size and shape variations on the results.

The buccal cusps being the functional cusps in mandibular molars and the mesial marginal ridge is also subjected to masticatory load, in all the root canal treated samples, the mesial wall was removed to simulate the clinical situation. Loss of one or more marginal ridges weakens the tooth and makes it more susceptible to fracture [10]. Reeh *et al.* stated that it is the loss of marginal ridges that was primarily responsible for the change in stiffness [11].

For oblique loading, the teeth were mounted at an angulation of 45^{o} to long axis in epoxy resin so that the load can be applied at an angle of 135^{o} to the buccal cusps (corresponding to the component of force along the buccal cuspal inclines of mandibular molar in lateral excursion). Such a choice was based on different gnathologic considerations trying to accomplish the best load simulation of occlusion during function.

Cyclic loading is continued until failure and the results are reported as the number of cycles to failure, or as the number of failures when cyclic loading was stopped. Maximum masticatory force is variable between experiments but generally falls within the range of 500-800 N. The maximum bite force in patients with bruxism is 911 N in the molar region and 569 N in the incisor region [12]. But in the present study, to cause a fracture in specimens, a range of 0-800N was applied at a crosshead speed of 0.5mm/min. If mechanical resistance to fracture is investigated, specimens should be loaded until a fracture occurs [13].

When comparing the number of cycles to fracture, composite core showed maximum resistance, followed by amalgam and least was by glass ionomer cement. Adhesive restorations efficiently transmit and distribute functional stresses across the bonding interface to the tooth and reinforce weakened tooth structure. Reel et al. showed that maxillary premolars when restored with bonded composite resins were approximately 100% stronger than unrestored premolars, but Joynt *et al.* reported only a 23% increase in strength [14]. Composites bond to the tooth structure micro-mechanically and provide a good marginal seal, reinforcement of remaining tooth structure and conservation of tooth structure. Literature shows that it can absorb and distribute forces uniformly, thereby increasing resistance to fracture and providing an improved prognosis [15].

Alkasite showed better fracture resistance than glass ionomer cement. According to Chowdhury *et al.* in 2018, under compressive loading, alkasite significantly strengthen teeth after Class II cavity preparation and restoration in molars but dental amalgam showed comparatively inferior results [16]. Alkasite redefines the conventional restoration by combining various properties like bulk placement, ion release and durability in a dual-curing, which is a highly esthetic product [21]. The Isofiller I acts as a shrinkage stress reliever that minimizes shrinkage force, whereas the organic/inorganic ratio, as well as the monomer composition of the material, is responsible for the low volumetric shrinkage. The flexural strength of alkasite is greater than 110 MPa which makes it a long-lasting material in the stress-bearing posterior region. [22]. Mazumdar *et al.* demonstrated a better microhardness with alkasite compared to silver amalgam, GIC and nanohybrid composite, and it is becoming a more clinically suitable option for minimally invasive treatments [23]. Similar to their study, our study also showed that alkasite can be used in high stress-bearing areas as a restorative material.

Compared to raising a single load to fracture, subjecting the specimens to cyclic loading and then determining their reaction to fatigue will more accurately simulate intraoral conditions. Most laboratory studies have reported a greater mean fracture resistance than maximum bite force, which is in the range of 420±112 N to 632±174 N [17]. Static laboratory tests such as fracture resistance or load-bearing capacity measurements do not simulate the dynamic oral conditions as they are resulted due to the forces, which are constantly changing rate, magnitude and direction. Therefore, laboratory studies performing cyclic mechanical loading and long-term clinical evaluation studies are, in the majority of cases, the most reliable evidence sources [18].

The results of this present study demonstrated that the specimens restored with composite exhibited the highest fracture resistance when subjected to oblique cyclic loading, followed by specimens restored with amalgam, alkasite. The least resistance was observed with the type IX GIC core group.

Despite the fact that large quantities of evidence are still missing, it can be stated that the restoration of nonvital teeth has evolved from a completely empirical approach to biomechanically driven concepts, the conservation of remaining sound tooth structure, selection of material and adhesion being the most relevant elements for improved long-term success. Although the method used, endeavoured to simulate the clinical situation in all stages, a limitation of this study is the fact that it was performed *in vitro,* and the results should be directly extrapolated to the clinical situations.

5. Conclusion

From the results of this study, composite is considered to be the best core build-up material. The newer material, alkasite can bear stress almost as that of amalgam restorations, therefore it can be considered as core material for the restoration of endodontically treated teeth.

Conflicts of interest: Authors declared no conflicts of interest.

Financial support: None

References

1. Trushkowsky RD. Restoration of endodontically treated teeth: criteria and technique considerations. Quintessence Int. 2014;45(7):557–567.
2. Combe EC, Shaglouf AM, Watts DC, Wilson NH. Mechanical properties of direct core build-up materials. Dent Mater. 1999;15(3):158–165. https://doi.org/10.1016/S0109-5641(99)00027-5
3. Nujella BPS, Choudary MT, Reddy SP, Kumar MK, Gopal T. Comparison of shear bond strength of aesthetic restorative materials. Contemp Clin Dent. 2012;3(1):22–26. https://doi.org/10.4103/0976-237X.94541
4. Monga P, Sharma V, Kumar S. Comparison of fracture resistance of endodontically treated teeth using different coronal restorative materials: An in vitro study. J Conserv Dent JCD. 2009;12(4):154–159. https://doi.org/10.4103/0972-0707.58338
5. Peroz I, Blankenstein F, Lange K-P, Naumann M. Restoring endodontically treated teeth with posts and cores--a review. Quintessence Int. 2005;36(9):737–746.
6. Gillen BM, Looney SW, Gu L-S, Loushine BA, Weller RN, Loushine RJ, et al. Impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment: a systematic review and meta-analysis. J Endod. 2011;37(7):895–902. https://doi.org/10.1016/j.joen.2011.04.002
7. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J. 1995;28(1):12–18. https://doi.org/10.1111/j.1365-2591.1995.tb00150.x
8. Rosenstiel SF, Land MF. Contemporary Fixed Prosthodontics. Elsevier Health Sciences; 2015.
9. Musanje L, Darvell BW. Aspects of water sorption from the air, water and artificial saliva in resin composite restorative materials. Dent Mater. 2003;19(5):414–422. https://doi.org/10.1016/S0109-5641(02)00085-4
10. Palamara JEA, Palamara D, Messer HH. Strains in the marginal ridge during occlusal loading. Aust Dent J. 2002;47(3):218–222. https://doi.org/10.1111/j.1834-7819.2002.tb00332.x
11. Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod. 1989;15(11):512–516. https://doi.org/10.1016/S0099-2399(89)80191-8
12. Vârlan C, Dimitriu B, Vârlan V, Bodnar D, Suciu I. Current opinions concerning the restoration of endodontically treated teeth: basic principles. J Med Life. 2009;2(2):165–172. https://doi.org/10.1067/mpr.2002.123849
13. Heydecke G, Butz F, Hussein A, Strub JR. Fracture strength after dynamic loading of endodontically treated teeth restored with different post-and-core systems. J Prosthet Dent. 2002;87(4):438–445. https://doi.org/10.1067/mpr.2002.123849
14. Daneshkazemi A. Resistance of bonded composite restorations to fracture of endodontically treated teeth. J Contemp Dent Pract. 2004;15(3):51–58. https://doi.org/10.5005/jcdp-5-3-51
15. 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 JCD. 2016;19(2):111–115. https://doi.org/10.4103/0972-0707.178682
16. Chowdhury D, Guha C, Desai P. Comparative Evaluation of Fracture Resistance of Dental Amalgam, Z350 Composite Resin and Cention-N Restoration In Class II Cavity. Int Organ Sci Res. 2018;17(4):52–56. https://doi.org/10.1016/j.archoralbio.2014.05.005
17. de Abreu RAM, Pereira MD, Furtado F, Prado GPR, Mestriner W, Ferreira LM. Masticatory efficiency and bite force in individuals with normal occlusion. Arch Oral Biol. 2014;59(10):1065–1074. https://doi.org/10.1111/iej.12538
18. Aurélio IL, Fraga S, Rippe MP, Valandro LF. Are posts necessary for the restoration of root filled teeth with limited tissue loss? A structured review of laboratory and clinical studies. Int Endod J. 2016;49(9):827–835.
19. Krejci, I., Duc, O., Dietschi, D. & de Campos, E. Marginal adaptation, retention and fracture resistance of adhesive composite restorations on devital teeth with and without posts. Oper. Dent. 2003;28(2):127-35.
20. Sorrentino R, Monticelli F, Goracci C, Zarone F, Tay FR, García-Godoy F, Ferrari M. Effect of post-retained composite restorations and amount of coronal residual structure on the fracture resistance of endodontically-treated teeth. Am J Dent. 2007;20(4):269-74.
21. Jagvinder singh mann, Sunakshi sarma. Cention N: A Review. Int J Curr Res. may2018;10(05):69111–2.
22. Sharma A, Das S, Thomas MS, Ginjupalli K. Evaluation of fracture resistance of endodontically treated premolars restored by alkasite cement compared to various core build-up materials. Saudi Endodontic Journal. 2019;9(3):205.
23. Mazumdar P, Das A, Guha c. Comparative evaluation of hardness of different restorative materials (restorative gic, cention n, nanohybrid composite resin and silver amalgam) – an in vitro study. Int J Adv Res. 2018 Mar 31;6(3):826–32. https://doi.org/10.21474/IJAR01/6737

Linju V, Prabath SinghV.P., Madhu H, Presannakumar G. Evaluation of effect of core build-up materials on fracture resistance of endodontically treated teeth. Int J Dent Mater. 2022;4(2):37-41. *http://dx.doi.org/10.37983/IJDM.2022.4203*