A COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDODONTICALLY TREATED TEETH RESTORED WITH SDR FLOW PLUS, BEAUTIFILL, TETRIC N FLOW AS CORE BUILDUP MATERIALS: AN IN-VITRO STUDY

DISSERTATION

Submitted to

BABU BANARASI DAS UNIVERSITY, LUCKNOW, UTTAR PRADESH

In the partial fulfilment of the requirement for the degree

of

MASTER OF DENTAL SURGERY

In the subject of

CONSERVATIVE DENTISTRY & ENDODONTICS

Submitted by

DR. ANANYA JAIN

Under the guidance of

DR. B. RAJKUMAR

DEPARTMENT OF CONSERVATIVE DENTISTRY & ENDODONTICS

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES, LUCKNOW

Batch: 2019-22 Enrolment No.: 11903222216

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled **"A comparative evaluation of fracture resistance of endodontically treated teeth restored with SDR Flow Plus, Beautifill, Tetric N Flow as core buildup materials: An in-vitro study"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. B. Rajkumar**, Professor and Head, Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

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Signature of the Candidate

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DEPARTMENT OF CONSERVATIVE DENTISTRY & ENDODONTICS

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCE, LUCKNOW.

CERTIFICATE BY THE GUIDE/CO-GUIDE

This is to certify that the dissertation entitled **"A comparative evaluation of fracture resistance of endodontically treated teeth restored with SDR Flow Plus, Beautifill, Tetric N Flow as core buildup materials : An in-vitro study"** is a bonafide work done by **Dr. Ananya Jain**, under our direct supervision & guidance in partial fulfillment of the requirement for the degree of **Master of Dental Surgery (M.D.S.)** in the speciality of Conservative Dentistry and Endodontics.

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ENDORSEMENT BY THE HOD

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ENDORSEMENT BY THE HEAD OF THE INSTITUTE

This is to certify that this dissertation entitled **"A comparative evaluation of fracture resistance of endodontically treated teeth restored with SDR Flow Plus, Beautifill, Tetric N Flow as core buildup materials : An in-vitro study"** is a bonafide work done by **Dr. Ananya Jain**, under the direct supervision & guidance of **Dr. B. Rajkumar,** Professor and Head, Department of Conservative Dentistry & Endodontics, Babu Banarasi Das College of Dental Sciences, Babu Banarasi Das University, Lucknow, Uttar Pradesh.

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As it has been rightly said,

णमोअरिहंताणं,

णमोसिद्धाणं,

णमोआयरियाणं,

णमोउवज्झायाणं,

णमोलोएसव्वसाहूणं।

एसोपंचणमोक्कारो, सव्वपावप्पणासणो।

मंगलाणंचसव्वेसिं, पडममहवईमंगलं।।

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At last I beg for forgiveness from those, whose names I have inadvertently missed but they should find solace that their knowledge has been extended to others by way of this thesis.

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LIST OF ABBREVIATIONS

S. NO.	Abbreviation	Full form
1.	SDR	Smart Dentin Replacement
2.	CEJ	Cemento enamel junction
3.	FRC	Fiber Reinforced Composite
4.	GFP	Glass Fiber Post
5.	PVC	Polyvinyl chloride
6.	RB	Restorative bulkfill
7.	FB	Flowable bulkfill
8.	EFX	EverX Flow
9.	FBF	Filtek bulkfill

CONTENTS

ABSTRACT

Aim: The aim of this study is to compare and evaluate the fracture resistance of endodontically treated teeth restored with SDR Flow Plus, Beautifill, Tetric N flow as core buildup materials.

Methodology: A total of 30 maxillary central incisors were extracted and collected. The samples were decoronated 2mm above the level of CEJ to provide a uniform ferrule height of 2mm for all samples. Cleaning and shaping od the samples were done using Protaper Gold rotary files to a size of F2. Obturation for all the teeth was carried out to provide an apical seal of 5mm.The samples were divided into 3 groups of10 teeth each according to different core buildup materials used. Group 1 - Tetric N Flow, Group 2 - Beautifill, Group 3 – SDR flow plus. After the post space preparation the Ribbond post was luted into different groups using respective bulkfill flowable resin materials which also acted as luting agents. After core buildup, crown preparation was done for each group and a porcelain fused to metal crown was prepared and luted onto each sample. Each specimen was then held in place for testing in a special jig with its long axis inclined facially, at an angle of 135^0 and subjected to a load on a universal testing machine at a crosshead speed of 0.5 mm/minute until failure occurred.

Results: The mean compressive load for group 3- SDR flow plus was the highest followed by group 1- Tetric N Flow and then by group 3- Tetric N Flow and least for group 2- Beautifill bulk fill flowable materials.

Conclusion: This study suggests that bulkfill flowable materials can also be used as core buildup materials as well as luting cements when placed wisely in increments of 4mm. This study dictates the use of a fiber reinforced composite post to be used along with the cement since it allows thorough polymerization of luting resin cement. The newly introduced Bulkfill flowable corebuildup material-SDR Flow Plus showed the maximum compressive strength values. However, more studies need to be conducted to clinically evaluate for its mechanical properties with other materials and luting agents.

Keywords: SDR Flow Plus, Tetric N Flow, Beautifill, Bulkfill flowable materials, maxillary central incisor.

INTRODUCTION

For a successful treatment of a badly broken tooth having pulpal disease, endodontic treatment is not sufficient enough.[1] Also caries, access cavity preparation and shaping procedures generally lead to loss of structural integrity of a tooth.[2]This tooth also needs a prosthetic reconstruction after completion of endodontic therapy.[3] It has been suggested that over a period of time endodontically treated teeth dry out and there are changes in the dentinal collagen cross linking. These changes make the tooth brittle and more susceptible to fracture in comparison to a vital tooth.[4]

In studies reported by *Glantz and Randow,*[5] the protective feedback mechanism of the tooth is lost after pulp extirpation which is also a contributing factor to fracture of tooth. This leads to a greater fracture rate of an endodontically treated tooth as compared to a normal i.e. a vital tooth since it is not able to withstand the forces generated by mastication.[6] These changes when combined also result in decreased translucency and increased fracture susceptibility of the tooth.[7] It therefore remains a challenging task to restore the overall condition and longevity of the tooth.

So in such cases where there is not enough of remaining tooth structure to retain the core, a post is indicated. Therefore, the main function of an endodontic post is to retain the core when the remaining tooth structure is missing or not enough.[8]

Posts can be categorized into two main categories as custom made post and prefabricated posts.[9] Under custom made posts – cast gold posts and cores are conventional.[10] These posts have been used since time and again to support the final restoration. According to restrospective studies, they have a clinical success rate of 90.6%. These materials were inert and had coefficient of thermal expansion ($\approx 15\ [C^{-1}] \times 10^6$) and modulus of elasticity (14.5×10^6 psi) similar to that of enamel.[11] Also they were able to withstand normal occlusal forces and had good compressive strength values. However there major disadvantage was their cost and esthetics since the metal showed under all ceramic restorations. Other base metal alloys were also used but their major disadvantage was their strength. They required lab fabrication and two visits. To overcome these disadvantages, prefabricated posts came into use. Prefabricated posts can be titanium post, stainless steel posts, ceramic and fiber reinforced polymers.[12] Among these, titanium posts showed low fracture strength values, stainless steel posts showed nickel sensitivity.(13)

After endodontic treatment the permanent restoration should essentially be a bonded restoration since it minimizes microleakage and contamination. Restorative dentistry also determines the prognosis of a tooth. Studies by *Panitvisai and Messer*(14) have shown that posterior teeth do require cuspal coverage after endodontic treatment. In a retrospective study done by *Aquilino and Caplan*(15) on 400 teeth in a 9 year period, they found out that endodontically treated teeth that were provided with cuspal coverage were 6 times more likely to survive than those restored by intracoronal restorations.However, in studies reported by *Scurria et al*(16) it was found that only 50% of endodontically treated tooth are provided by a cuspal restoration or coverage. Similar findings were reported by Eckerbom and *Magnusson*.(17) It should therefore be noted that preserving the tooth structure is of utmost importance when restoring a tooth. Preservation of coronal tooth structure provides resistance and retention form for the crowns. For this, different types of post materials are available which include cast metal or prefabricated metal post, composite post or post made up of any biologic material. There are several factors that determine post selection. Also knowledge of the anatomy of root and various post system is important to prevent procedural errors like excess dentin removal, deviation and perforations. Length of the post is recommended to be two thirds of the root length or atleast same as that of clinical crown. Some case studies also show that shorter post lengths also provide a favourable prognosis. An endodontically treated tooth is more susceptible to fracture depending on the amount of residual root dentin remaining. Also the use of irrigants and gutta percha condensation pressure leads to root weakening. Other factors which also have a similar effect are excessive canal enlargement, internal resorptions, root caries and post removal making restoration of tooth a challenge. The presence of 1.5-2mm coronal dentin after tooth preparation also known as “ferrule” is also a major contributory factor that determines the performance of the post restorations.(18) The aim of providing a ferrule is for redistribution of stresses exerted on outer coronal third of root which potentially changes the fracture pattern of tooth to the one that can be easily repaired.

In permanent dentition, maxillary incisor region is the site for most common types of traumas that cause coronal fractures.[19] But it has been noted, that an anterior teeth with post placement is thrice more susceptible to fracture than a posterior teeth due to the fact that they are subjected to higher horizontal forces as a result of their location in the arch. Such teeth require a quick esthetic and functional treatment. But restoring such teeth is more challenging; therefore, the selection of a suitable post and core system that could dissipate occlusal forces to the tooth and its surrounding tissues is crucial to avoid root fracture.

In recent years, particularly for anterior tooth restorations, glass fiber posts have gained acceptance since their modulus of elasticity is similar to that of dentin which allows them to evenly dissipate the masticatory forces which is not observed with cast metal post or prefabricated metal. They also proved to be a better alternative due to corrosion resistance and esthetics that they provided. Fiber reinforced posts can be Carbon fiber posts, Prefabricated glass and quartz-fiber posts, Individual glass fiber posts, Polyethylene fiber posts, Hollow fiber posts.[20] Among these posts recently, Ribbond – a fiber reinforced composite post has gained popularity and has several indications due to the high strength woven polyester bondable ribbon.[21] It is made up of plasma treated ultra high molecular weight polyethylene fibers which are woven into three dimensional structure, leno wave or triaxial braid. Apart from being used as a post material it has several other indications like being used as a periodontal splint, a fiber reinforced composite restoration, orthodontic retainer, single visit bridge, trauma stabilization, Acrylic/Bis – Acryl provisional bridge, single visit bridge.

As a post material, they have the several advantages also for example, they provide a specific high mechanical interlocking due to special arrangement of patterns of interlocking threads. It also provides as a good chemical bond to resin based materials since the fibers are subjected to cold gas plasma treatment to reduce their superficial tension. Studies have shown that this arrangement has provided good retention and fracture strength values which is important for the clinical success of the post. Part from that there is no possibility of root perforation. Natural strength of the tooth is maintained since there is no additional tooth removal after root canal treatment. Its pliable state provides a good mechanical retention since it adapts to the natural contours and undecuts of the canal. This post is highly passive and retentive and the tooth post interface has no stress concentration. Its translucent fibers allow natural transmission of light through the teeth and the crown and take on the color of the composite.

However, their high price limits their use in daily practice despite its excellent properties and has several contraindications also. They cannot be given in teeth that have failed the endodontic treatment or have ambiguous and poor prognosis, teeth with poor periodontal status like increased mobility or weak and fragile roots. Also where there is sufficient amount of tooth structure present and can be restored without a post.

In combination with FRC post, the composite core build-up material is often used to restore the coronal portion of the teeth and to achieve retention and resistance form for the crown. Composite resin is a common material used for core build-up to strengthen lost tooth structure.(22)In comparison to zinc phosphate cement which was used conventionally, resin based cements have been used widely and tremendously as luting cements. It is to be noted that they also have the capability to reinforce thin root canal walls. However, it needs to be restored using an incremental technique to ensure proper polymerization which can leave voids and gaps due to the difficulty during placement in a deep cavity along with problems of microleakage, marginal discoloration and secondary caries. Therefore, bulk fill resin composites have been introduced to overcome the problem of layering techniques leading to voids or contamination between layers and one step curing of 4-5 mm increments.(23) Also filling the cavity in bulk has some added advantages like less time consumption and less window of opportunity for procedural errors like incorporation of voids and contamination.

The bulk fill composites can be categorized into two categories: Base and full body bulkfill composites. The base bulkfill composites due to its low viscosity as the tendency to flow which enables them to be placed through a small nozzle from a syringe and allows for their good adaptation in unaccessible areas and eases their placement. Also they have low filler content leaving their surface less wear resistant. Therefore, they are also called as flowable bulk fill composites.(24) However, the full body bulkfill composite have high filler content, high viscosity and more wear resistance value and are regarded as true bulkfill composites.

Since there is a lot of debate whether or not to use a flowable bulkfill composite for post and core buildup or luting fiber reinforced composite resin post in endodontically treated anterior teeth in the presence of ferrule and due to less literature on the this topic, this research was conducted to assess the load bearing capacity of endodontically treated anterior teeth reinforced with fiber reinforced composite post which were luted and restored with flowable bulkfill composites and later by porcelain fused to metal crowns. The null hypothesis was that the fracture strength of all the teeth with different materials used up as luting agents and for core buildup would be the same.

AIM AND OBJECTIVES

Aim of the study:

The aim of this study was to compare and evaluate the fracture resistance of endodontically treated teeth restored with SDR Flow Plus, Beautifill, Tetric N flow as core buildup materials.

Objectives of the study:

1) To evaluate the fracture resistance of teeth restored with Tetric N flow.
2) To evaluate the fracture resistance of teeth restored with Beautifill.
3) To evaluate the fracture resistance of teeth restored with SDR Flow Plus.
4) Inter-group comparison of core buildup materials i.e Tetric N flow, Beautifill and SDR Flow Plus.

REVIEW OF LITERATURE

1. **SG Ahn, JA Sorensen (2003)** [25] compared the flexural strength and modulus of elasticity of core materials and measured the bending strength of post systems made of a variety of materials. Results showed that Clearfil Photo Core and Luxacore had flexural strengths approaching amalgam, but their modulus of elasticity was only about 15% of that of amalgam. The strengths of the glass ionomer and resin modified glass ionomer were very low. The heat pressed glass ceramic core had a high elastic modulus but a relatively low flexural strength approximating that of the lower strength composite resin core materials. The stainless steel, zirconia and carbon fiber post exhibited high bending strengths. The glass fiber posts displayed strengths that were approximately half of the higher strength posts. It was concluded that when moderate amounts of coronal tooth structure are to be replaced by a post and core on an anterior tooth, a prefabricated post and high strength, high elastic modulus core may be suitable or zirconia post and pressed core are desirable.
2. **Mitsui FH, Marchi GM, Pimenta LA, Ferraresi PM (2004)**[26] evaluated in vitro the fracture resistance of bovine roots restored with five different intraradicuiar post systems: cast post and core; titanium post; carbon-fiber post; glass-fiber post; and zirconium-oxide post and found that titanium posts presented higher mean values of fracture resistance when compared to glass-fiber posts and zirconium-oxide posts and similar values compared to carbon-fiber posts. Also, roots treated with cast posts and cores presented similar results when compared to roots treated with prefabricated posts and hence, it was concluded that all prefabricated intraradicular post systems evaluated presented similar resistance to fracture when compared to cast posts and cores, and among the prefabricated ones, titanium and carbonfiber posts could be best indicated.
3. **S. Belli, A. Erdemir, M. Ozcopur, G. Eskitascioglu (2005)**[27] evaluated the effect of using flowable composite with or without leno woven ultra high modulus polyethylene fibre reinforcement on fracture resistance of root filled mandibular molars with mesio-occluso-distal (MOD) preparations. Results showed that the use of flowable composite resin under composite restorations had no effect on fracture resistance of root filled molar teeth with MOD preparations and use of polyethylene ribbon fibre under composite restorations significantly increased fracture strength.

4. **Z Salameh, F Papacchini, HF Ounsi, C Goraccid, E Tashkandie, M Ferrarif (2006)[(28)]** evaluated the bond strengths between various resin composites used as core materials (Multicore Flow, Tetric Flow, Filtek, Tetric Ceram, Filtek Z250), and an FRC post (FRC Postec Plus) by means of the microtensile nontrimming technique. The statistical analysis revealed that MultiCore Flow achieved significantly higher bond strengths than Filtek Flow, Tetric Ceram, and Filtek Z250). The bond strength of Tetric Flow was significantly higher than that of Filtek Z250 and it was concluded that for core buildup on a fiber post, dual-cure composites appear to be preferable to light-curing composites.
5. **FT Sadek, F Monticelli, C Goracci, FR Tay, Marco Ferrari (2007)[(29)]** evaluated the microtensile bond strengths of different resin composites used as core materials around fiber posts. Forty DT Light-Posts (RTD) were randomly divided into eight groups, according to the resin composite used. They included two core materials specifically developed for core build-up—Group 1: Core-Flo (Bisco Inc.) and Group 2: UniFil Core (GC Corp.); three hybrid composites—Group 3: Tetric Ceram (Ivoclar-Vivadent), Group 4: Gradia Direct (GC Corp.), Group 5: Bisfil 2B (Bisco, Inc.); and three flowable composites—Group 6: Æliteflo (Bisco, Inc.), Group 7: Filtek Flow (3M ESPE) and Group 8: UniFil Flow (GC Corp). A cylindrical plastic matrix was placed around the silanized post and filled with the respective resin composite. Each bonded post provided five to eight sticks for microtensile testing. Each stick was loaded to failure under tension at a cross-head speed of 0.5 mm/min. One-way ANOVA and Tukey's test were used for statistical analysis. Scanning electron microscopy (SEM) was used to evaluate the interface of the fractured sticks. Resin composites exhibited a significant influence on microtensile bond strength ($p < 0.05$). Core-Flo showed the highest bond strength (11.00 ± 0.69 MPa) although it was not statistically significantly different from all groups, except from the flowable composites. Under SEM, all the composites adapted well to the fiber post, with a variable extent of voids observed along the fractured composite interfaces and it was concluded that although good adaptation to the post surface was achieved, bond strength to fiber post remains relatively weak. It was concluded that core build-up and hybrid composites are better alternatives to flowable composites as core build-up materials.

6. **S Ferrier, BS Sekhon, PA Brunton (2008)[(30)]** conducted an in vitro study and compared the fracture resistance of coronal-radicular restorations made from three different direct restorative materials - amalgam, composite and resin-modified glass ionomer. It was concluded that endodontically-treated premolars restored with amalgam corono-radicular restorations exhibited greater fracture resistance compared to equivalent teeth restored with resin-modified glass ionomer cement and composite.
7. **Gurbuz T, Sengul F, Altun C (2008)[(31)]** conducted an in vitro study to determine the effect on the distribution of stress with the use of short-post cores and over restorations composed of different materials. The restorative materials used were namely two different composite resin materials (Valux Plus and Tetric Flow), a polyacid-modified resin material (Dyract AP), and a woven polyethylene fiber combination (Ribbond Fiber + Bonding agent + Tetric Flow). Finite element analysis (FEA) was used to develop a model for the maxillary primary anterior teeth. The results of FEA showed that the mechanical properties and elastic modulus of the restorative material influenced the stresses generated in enamel, dentin, and restoration when short-post core restorations were loaded incisally. This led to the conclusion that resin-based restorative materials with higher elastic moduli were found to be unsuitable as short-post core materials in endodontically treated maxillary primary anterior teeth.
8. **F Keulemans, P Palav, MMN Aboushelib, A van Dalen, CJ Kleverlaan, AJ Feilzer (2009)[(32)]**evaluated *in vitro* the influence of fiber-reinforcement on the fracture strength and fatigue resistance of resin-based composites.It was concluded that the fatigue resistance of resin-based composites is lower than their fracture strength and FRC are more fatigue resistant than PFC or combinations of FRC and PFC.

9. **NT Al-Kuriane – Al-Qadisiyah Medical Journal (2010)[(33)]** compared the the effect of using flowable composite with or without ultra high modulus polyethylene fiber reinforcement on fracture resistance of root filled mandibular molars with mesio - occluso-distal(MOD) preparations. Thirty sound extracted human mandibular molars were randomly assigned to three groups (n=10). All teeth were root filled and MOD cavity preparation were created.Group (1) was restored with a dentine bonding system(DBS: SE Bond) and composite resin(CR). In group (2), flowable composite resin (Protect liner F) was used before restoring teeth with CR. In group (3) leno

woven ultra high modulus polyethylene ribbon fiber (Ribbond, Seattle, WA. USA) was inserted into the cavities in a buccal to lingual direction and teeth were then restored with DBS and CR. After finishing and polishing the specimens were stored in 100% humidity at 37CÂ° for 1 day. Compressive loading of the teeth was performed using a universal testing machine at a crosshead speed of 0.5 mm/min. the mean load necessary to fracture the samples were recorded in newtons (N) and were subjected to analysis of variance (ANOVA) and Tukey test. The results led to the conclusion that the use of flowable composite resin under composite restorations had no effect on fracture resistance of root filled molars teeth with MOD preparation. while the use of polyethylene fibre under composite restorations in root filled teeth with MOD preparations significantly, increased fracture strength .

10. **R Silva, PCF Santos-Filho, PC Simamoto-Júnior, LR Martins, AS Mota , CJ Soares (2011)[(34)]** evaluated the effect of post types and restorative techniques on the strain, fracture resistance, and fracture mode of incisors with weakened roots. One hundred five endodontically treated bovine incisors roots (15 mm) were divided into 7 groups (n=15). The two control groups were (C) intact roots restored with Cpc (cast posts and core) or Gfp (glass fiber posts). The five experimental groups were (F) flared roots restored with GfpAp (Gfp associated with accessory glass fiber posts), GfpRc (anatomic Gfp, relined with composite resin), and GfpRcAp (anatomized Gfp with resin and accessory glass fiber posts). All teeth were restored with metal crowns. Mechanical fatigue was performed with 3x105/50 N. Specimens were loaded at 45o, and the strain values (μS) were obtained on root buccal and proximal surfaces. Following that, the fracture resistance (N) was measured. One-way ANOVA and Tukey's HSD tests (α=0.05) were applied, and failure mode was checked. No significant difference in strain values among the groups was found. Cpc presented lower fracture resistance and more catastrophic failures in flared roots. It was concluded that Gfp associated with composite resin or accessory glass fiber posts seems to be an effective method to improve the biomechanical behavior of flared roots.
11. **P Shah, SC Gugwad, C Bhat, R Lodaya (2012)[(35)]** evaluated the effect of endodontic treatment on the fracture resistance of the tooth and reinforcing ability of three different core materials namely IRM, silver amalgam , GIC. Result showed a drastic reduction in the fracture resistance of the tooth on access opening (1/3rd) and

out of the three core materials glass ionomer was shown to be the best core material giving the highest fracture registrance followed by silver amalgam and IRM. It was concluded that endodontic treatment decreases strength of the tooth approximately 1/3rd of the sound tooth in case of occlusal access cavity preparation and GIC core gives the highest fracture resistance value followed by amalgam and IRM.

12. **N Jayanthi, V Vinod (2013)[(36)]** conducted an in vitro study to compare the mechanical properties of materials used for direct core foundations. The differences between the compressive strength and flexural strength of Filtek Z350 nanocomposite with conventional core build up materials like Amalgam, Vitremer GIC and Fluorocore were tested. The results of the study showed that Fluorocore had the highest compressive strength and flexural strength followed by Filtek Z350 [nanocomposite] Amalgam had the least flexural strength and Vitremer GIC had the least compressive strength concluding that flurocore and nanocomposite are stronger than other core build up materials and hence should be preferred over other conventional core build up materials in extensively damaged teeth.
13. **RS Mosallam, MF Haridy (2014)[(37)]** onducted an in vitro study to verify the fracture resistance of premolar teeth with standardized mesioocclusodistal (MOD) preparations restored with different resin composites and layering protocols. Seventy sound maxillary premolar teeth with standardized MOD cavities were randomly allocated to seven groups (n=10): G1 (control): sound teeth; G2: unrestored MOD preparation; G3: was filled by an increment technique with nanohybrid resin composite (Grandio, Voco); G4: was filled in bulk with flowable composite (x-tra base, Voco); G5: bulk filled with multi hybrid composite (x-tra fil, Voco); G6: was restored by increment technique with x-tra base / x-tra fil and G7: was filled in increment with x-tra base/Grandio. After being stored 24 hours at 37o C, specimens were subjected to a 4mm diameter steel sphere in a universal testing machine at a cross-head speed of 5mm/min until fracture occurred. D'Agostino-Pearson test, Kruskal–Wallis test and Mann–Whitney U tests at a 5% significance level were used to determine the statistical differences among groups. Results showed that a significant difference resulted between tested groups on mean fracture resistance. Groups G1, G6 and G7 showed the highest mean fracture resistance followed by group G3 and G5 with an insignificant difference between each other. The lowest mean fracture resistance resulted for G2 and G4.It was concluded that bulk fill

flowable composite lining under resin composite layering improve fracture resistance. Moreover, bulk fill flowable resin composite should be covered by methacrylate based resin composite.

14. **Didem A, Yalcin G (2014)[(38)]** compared the flexural and compressive strengths of a new sonicactivated bulk-fill system (Sonicfill) with other bulk-fill resins and a universal posterior composite resin - SDR, Tetric Evo Ceram, GC G-aeniall system were compared. It was found that due to the ability to place restorations with single increment and ease of use, the Sonicfill system can be an alternative for posterior restorations.
15. **Furness A, Tadros MY, Looney SW, Rueggeberg FA (2014)[(39)]** examined the effects of composite type (bulk-fill/conventional) and placement (4-mm bulk/2-mm increments) on internal marginal adaptation of Class I preparations. Restored using either a bulk-fill (SureFil SDR Flow (SDR), Quixx (QX), SonicFill (SF), Tetric EvoCeram Bulk (TEC)) or a conventional composite designed for 2-mm increments (Filtek Supreme Ultra (FSU). It was found that no significant differences in gap-free margins were found between placement methods within a given product per location. Except for SDR, percentage of gap-free margins was significantly lower at the pulpal floor interface than at the enamel interface for bulk-fill.
16. **Jain G, Narad A, Boruah LC, Rajkumar B (2015)[(40)]** conducted an *in-vitro* study to compare the shear bond strength (SBS) of three recently introduced dual-cure resin based core build-up materials namely ParaCore, FluoroCore, and MultiCore and it was concluded that MultiCore dual-cure resin based core build-up material showed the highest mean SBS as compared to FluoroCore and ParaCore. SBS was not negatively affected by thermocycling.
17. **Isufi A et al (2016)[(41)]** compared the fracture resistance of endodontically treated teeth restored with a bulk fill flowable material (SDR) and a traditional resin composite(EsthetX). It was found that no statistically significant differences were found among groups ($P<0.05$). This led to the conclusion that fracture resistance of endodontically treated teeth restored with a traditional resin composite and with a bulk fill flowable composite (SDR) was similar in both maxillary and mandibular molars and showed no significant decrease in fracture resistance compared to intact specimens.

18. **Nilavarasan N, Hemalatha R, Vijayakumar R, Hariharan VS (2016)**[(42)] compared the fracture resistance and the mode of failure among three different post materials in primary anterior teeth-Ribbond, Omega loop, and Glass fiber post. Pulp therapy was followed by intracanal post and crown buildup. The samples were mounted in self-cure acrylic and subjected to compressive strength test using universal testing machine (Instron). The mean compressive strength values of Ribbond, omega loop, and glass fiber post were found to be 83.25 N, 61.60 N, and 75.55 N, respectively and it was Concluded that Ribbond showed the highest fracture resistance values followed by Glass fiber post and Omega loop. Although there is difference in mean values, they were non-significant.
19. **Asia W (2017)**[(43)] to evaluate and compare the physical properties of two core build-up materials (ParaCore and CoreXflow) and compare this to conventional composite material (Filtek Supreme Plus and SDR Flow) used as core build-up material. The composite core materials specifically designed as core build up materials displayed a greater flexural strength compared to the conventional restorative composites used as core materials. A significant difference was found in the flexural strength of these materials. It was concluded that the physical properties of composites are greatly enhanced by alterations in their filler size and distribution of the filler. The filler component has a great influence on the dental composite’s ability to resist crack initiation and propagation, as well as its response to abrasion and contact loading leading to wear. The smaller filler sizes and greater filler loading of CoreXflow and ParaCore have shown to increase the flexural strength of these materials thus making them more superior for the use as core build-up material compared to conventional restorative composites.
20. **Jung JH, Park SH (2017)**[(44)] compared the marginal adaptation of flowable bulk fill resin-based composites - Filtek Z350, SDR, Venus Bulk Fill, Tetric N-Ceram and SonicFill Bulkfill, in MOD cavities *in vitro*. RB-RBCs showed better marginal adaptation than FB- RBCs. The lower level of polymerization shrinkage and polymerization shrinkage stress in RB-RBCs seems to contribute to this finding because it would induce less polymerization shrinkage force at the margin. FB-RBCs with lower flexural modulus may not provide an effective buffer to occlusal stress when they are capped with regular RBCs.

21. **Warangkulkasemkit S, Pumpaluk P (2018)[(45)]** conducted a study to evaluate the compressive strength, flexural strength, and microhardness of three commercial composite core build-up materials. All data were analyzed by oneway ANOVA and Tukey test methods (α=0.05). Flexural strength data were subjected to Weibull statistics analysis. All three groups presented significant differences in the compressive strength, flexural strength, and Knoop hardness. Filtek™ Z350 XT had the greatest compressive strength (MPa) and Knoop hardness while Filtek™bulk fill had the highest flexural strength. MultiCore®Flow had the lowest properties. With regard to the properties tested in this study it was concluded that bulk-fill resin composite can be used as an alternative to conventional resin composite for core build-up material.
22. **da Mota Martins V, Silva CF, Almeida LM, de Paula MS, de Sousa Menezes M, Santos-Filho PC(2019)[(46)]**evaluated the adhesive bond strength of glass fiber posts cemented with bulk-fill flowable resin in endodontically treated teeth, and the results were compared with those of glass fiber posts cemented with resin cement. Forty bovine incisor roots were selected and randomly divided into 2 groups (n = 20). The external surfaces of the roots were coated with a molding material. The canals were prepared, and then the fiber posts (Whitepost no. 2, FGM) were cemented with either resin cement (Allcem, FGM) (n = 20) or bulk-fill flowable resin (Opus Bulk Fill, FGM) (n = 20). Ten roots (n = 10) of each material were subjected to push-out and pull-out tests (EMIC DL 2000, Brazil) under compressive and tensile loading, respectively; a 50 N load cell and a constant crosshead speed of 0.5 mm/min was used for both tests. The testing data were analyzed using multifactorial analyses of variance two-way ANOVA and the Tukey test ($\alpha = 0.05$). Two skilled operators determined the failure modes of the samples using a stereomicroscope at 40× magnification with a 2.5D analysis. For push-out bond strength, there were no statistically significant differences between the root thirds in the bulk-fill flowable resin group and those in the resin cement group ($p = 0.536$). However, there were statistically significant differences ($p < 0.001$) among the root thirds within the same group. For pull-out bond strength, there were no statistically significant differences between the groups ($p = 0.739$). Therefore, the bulk-fill flowable resin exhibited similar results to those of the resin cement from the same manufacturer in terms of the cementation of glass

fiber posts, which suggests that bulk-fill flowable resin is a suitable alternative material for cementation.

23. **Franz M, Özcan M (2019)[(47)]** assessed adhesion of bulk-fill resin-composites as core and post materials only versus the use of fiber resin composite (FRC) posts. Human teeth ($N = 84$) were cut at the CEJ and endodontically treated and randomly divided into seven groups: TP: Titanium post (Flat Head T); SFRC: S2-glass FRC (Pinpost); EFRC1: E-glass FRC (GC Everstick) directly bonded; GFRC: E-glass FRC (Glassix Nordin); EFRC2: E-glass FRC (Everstick); BF1: Bulk-fill resin (Surefill SDR); BF2: Bulk-fill resin (SonicFill). Groups TP, SFRC, EFRC and GFRC were cemented (Panavia 21), while other groups were bonded directly to the intraradicular dentin. The core parts were constructed using a resin composite (G-aenial) except for Groups BF1 and BF2. The core-cervical dentin interface was loaded under shear forces. Push-out tests were performed in a Universal Testing Machine (1 mm/min). Data (MPa) were analyzed using two-way ANOVA and Tukey`s tests ($\alpha = 0.05$). Not the root level ($p > 0.05$) but the type of core and post material significantly affected shear and push-out bond results ($p < 0.001$). BF1 (9.2 ± 2.1) and BF2 (9.3 ± 3.1) showed significantly lower bond strength to the cervical dentin ($p < 0.05$) compared to other groups (11.6 ± 2.5–19 ± 6.8). FRC post types did not show significant difference being higher than those of TP, BF1 and BF2 (0.57 ± 0.37–2.34 ± 1.98) ($p > 0.05$). Partial cohesive core fracture was more common while BF1 and BF2 showed exclusively adhesive failures. Cohesive failure in the cement was frequent in Group TP (53%) compared to other groups (3–24%). BF1 and BF2 presented exclusively complete adhesive failure of the bulk-fill material.
24. **Aggarwal N, Jain A, Gupta H, Abrol A, Singh C, Rapgay T (2019)[(48)]** evaluated and compared the depth of cure of RBC's for posterior use: Sculptable bulk-fill composite – Tetric N-Ceram bulk fill (TNCBF), Flowable bulk-fill composites-TetricEvoflow bulk fill (TEFBF), Surefil SDR bulk fill (SDRBF), Dual cure bulk fill-Fill-Up (FDCBF) with conventional RBC-Esthet-X flow (EXF) and Filtex Z250 (FZ). Standardized polyacrylic mold was bulk filled with each of the six composites and light-cured for 20 s, followed by 24 h storage in water. The surface hardness was measured on the top and the bottom by recording Vickers hardness number by Vickers hardness indenter.

It was found that the mean bottom surface hardness value (HV) of SDR and TEFBF exceeded 80% of the top surface HV (HV-80%). Low viscosity bulk-fill composites (SDR and Tetric Evoflow) were properly cured in 4-mm increments. The TNCBF, high-viscosity composite, and Fill-Up, dual-cure bulk fill were not sufficiently cured in 4-mm increments. Hence, it was concluded that with increase in incremental thickness, HV decreased for the conventional resin composite but generally remained constant for the bulk-fill resin composites.

25. **Patil AM, Deshpande S, Ratnakar P, Patil V, Surabhi R, RezaKM (2020)[49]**determined the suitability of packable composite as Nayyar cores in comparison with other materials such as amalgam, resin-modified glass ionomer, and dual-cure composite resin. A total of 75 freshly extracted human mandibular premolars subjected for the study were stored in distilled water for not more than 4 months before the root canal filling procedure. They were then randomly divided into five groups, each group with 15 teeth. Amalgam showed higher resistance to fracture (1.82kN), and resin composite showed the least resistance to fracture (0.68kN). Resin-modified glass ionomer (0.96kN) and packable composite (0.93kN) showed almost similar fracture resistance. It was concluded thatpackable composite can be used as an alternative to amalgam core and resin-modified glass ionomer.
26. **Srinu G, Dayalan M, Nagabhairava RK, Thomas R, Fatima SR (2020)[50]** evaluated and compared the shear bond strength of different core materials. Eighty extracted non-carious permanent first molar teeth were randomly selected and embedded in an auto polymerizing pink acrylic resin. Specimens were selected on the basis of certain inclusion and exclusion criteria. Four commercially available brands of core materials were selected, (Bulk fill (IVOCLAR), Core X flow (DENTSPLY), Valux plus (3M ESPE) and Resin Modified Glass ionomer cement (GC)). The shear bond strength was tested using an Universal Testing Machine, (Mecmesin UK) using load cell of 500 N. The dimensions of the specimens were entered into the program for computation. The fracture sites along the dentin core materials interface was evaluated by Scanning electron microscope (Ultra 55, field emission scanning electron microscope, Karl Zeiss) to determine whether the fracture was adhesive or cohesive in nature. Results showed that higher mean shear bond strength was recorded for CORE X FLOW (GROUP II) group followed by BULK FILL (GROUP I) and VALUX PLUS (GROUP III) respectively. Lowest shear strength was recorded

for RESIN MODIFIED GIC (GROUP IV). It was concluded that resin modified glass ionomer cement can be used as a core build up material in situations where the tooth structure lost is minimal, as it the least shear bond strength and its use may be limited to anterior esthetic zone.

27. **Palaiyatharasi K (2020)**[51] compared the shear bond strength of three dual cure resin based core build-up materials Hard core (Pulpdent), Core x flow and Core Flo DC lite. Sixty Freshly extracted permanent human mandibular molar teeth were stored in distilled water at room temperature. The teeth were sectioned horizontally perpendicular to the long axis 1mm below the dentino enamel junction to expose the coronal dentin. The teeth were then randomly assigned to three groups on the basis of material used. Group A – Hardcore, Group B – Core x flow, Group C –Core Flo DC lite. The teeth were subjected to dentin surface treatment followed by placement of dual cure core build up material and thermocyled at 5°C-55°C for 500 cycles. Finally the samples were subjected to SBS test using Instron universal testing machine until the specimens fractured under stress load. Fractured Specimens were examined under scanning electron microscope and failure modes were analysed. The results of the study showed that the mean shear bond strength of core Flo DC lite, was the highest, followed by core x flow, Hard core Pulpdent. Among the three groups, shear bond strength values were mutually significant. Scanning electron microscope evaluation results showed cohesive and mixed failures in Group Band C and adhesive and mixed failures of Group A. However the failure modes were statistically insignificant. This may be due to the reduced sample size taken for the study. It was concluded that among the three groups, core flo dc lite performed better than core x flow and hard core (Pulpdent).
28. **Özyürek T, Topkara C, Koçak İ, Yılmaz K, Gündoğar M, Uslu G (2020)**[52]investigated the effects of different post and core systems, CAD/CAM crown placement on fracture strength of endodontically treated mandibular premolar teeth. One hundred forty single-rooted premolar teeth were randomly divided into a control group and six experimental groups as follows: control group (Group 1); Fiber Site post luting with Clearfil DC Core Plus (Group 2); RelyX Fiber post luting and core build up with Clearfil DC Core Plus (Group 3); RelyX Fiber post luting with Clearfil DC Core Plus and core build up with Filtek Bulk Fill Posterior (Group 4); specimens that received CAD/CAM crowns after the same procedures performed in

Groups 2, 3, and 4, respectively (Groups 5, 6, and 7). Fracture strength tests were performed, and the failure modes were recorded. Data were statistically analyzed using one-way ANOVA and post hoc Tukey tests. The highest fracture resistance was observed in the control group and among the experimental groups in Group 4. Groups 3 and 5 showed similar fracture resistance followed by Group 2. The lowest fracture resistances were seen in the samples of Groups 6 and 7. While the fracture strength of Group 2 increased after the crown placement (Group 5), the fracture strength of Group 3 and Group 4 decreased ($P < 0.05$). While the specimens in Groups 1, 2, 3, and 4 predominantly showed favorable failure, unfavorable failure was more frequent in Groups 5, 6, and 7.

29. **Abogabal AD, Goda AA (2020)**[(53)] conducted an in vitro study that sought to assess the effect of bulk fill flowable composite reinforced with short fibers on fracture resistance of maxillary premolar teeth that have extensively restored MOD cavities. The study comprised of 60 human maxillary sound premolar teeth that were randomly divided into 4 groups of 15 each. Group A comprised comprised of intact without any cavity (negative control). Wide MOD cavities were prepared using cylindrical bur with high-speed handpiece for the 3 other groups. Group B, the teeth with MOD cavities without any restoration (positive control); Group C, the teeth were restored with bulkfill flowable composite Tetric N flow bulk fill (Ivoclar Vivadent); and group D, the teeth were restored with short fibers reinforced bulkfill flowable composite ever X Flow(GC). The teeth were then stored in water at 37°C for 24h and their fracture resistance was assessed using (INSTRON) and it was concluded that extensive MOD cavities restored with bulk fill flowable composite having short fiber reinforcement, increased the fracture strength of teeth against compressive forces, with no difference than did the other bulk fill flowable composite.
30. **Yeo HW, Loo MY, Alkhabaz M, Li KC, Choi JJ, BarazanchiA (2021)**[(54)] conducted an in vitro study with the objective to compare the properties of bulk-fill direct restorative materials Filtek Z350 (CR), Filtek One Bulk Fill Restorative (BF), Fuji IX and EQUIA Forte (EF). Thirty specimens from each material were prepared according to ISO 4049 for three-point flexural strength. Elastic moduli and hardness (n = 20) were evaluated using nanoindentation. Depth of cure (DC) (n = 20) was measured for BF at three different depths (2, 3, 4 mm) and at two irradiation times (20 and 40 s). Wear testing was carried out for three different periods (3, 6, 12 month (s).

All specimens were stored in 37 °C water for 24 h prior to testing. Results were evaluated using one-way ANOVA followed by a post hoc Bonferroni test ($p < 0.05$). BF and CR showed a significantly higher flexural strength than other groups ($p < 0.05$), and the highest Weibull modulus was found in CR. BF showed sufficient DC with at least 85%, at all thicknesses. CR and BF also had a high level of translucency than EF and Fuji IX. Significant differences in flexural strength were found among all materials except between Fuji IX and EF. It was concluded that while all material tested were suitable for use clinically, BF and CR have superior properties than GIC based bulk-fill.

31. **Oliveira CR, Reis ÉG, Tanomaru-Filho M, Reis JM (2021)[(55)]**evaluated the fracture strength and failure modes of different core techniques in teeth with simulated coronal destruction. Forty teeth were endodontically prepared and the specimens were divided into four experimental groups ($n = 10$) according to the core composition: Filtek One Bulk Fill-*FOBF*, Filtek Z350 XT-*FZ350* (standard group), Filtek Bulk Fill Flow-*FBFF*, and LuxaCore Z-*LCZ*. CAD/CAM Monolithic zirconia crowns were obtained and cemented with RelyX U200. After storage in distilled water at 37°C for 48 h, the specimens were subjected to thermal cycling and to compressive strength mechanical tests. Statistical analyses ($\alpha = 0.05$) were performed by non-parametric Kruskal–Wallis, Dunn post hoc, and Fisher's exact tests.No significant differences ($p > 0.05$) were observed among *FOBF*, *FZ350*, and *FBFF* (mean ranks = 20.30, 12.20, and 23.20, respectively). *LCZ* (mean rank = 26.30) produced results similar to those of *FOBF* and *FBFF* ($p > 0.05$) and higher than those of *FZ350* ($p = 0.042$). The most frequent type of failure was irreparable, regardless of the experimental condition. The lowest percentages of reparable fractures were produced by *FOBF* group (10%). It was concluded that the use of bulk fill materials, including the "core-and-post" *LCZ* dual-cure resin composite, did not impair the fracture strength of endodontically treated teeth with coronal destruction.

32. **Kaur B, Gupta S, Grover R, Sadana G, Gupta T, Mehra M(2021)[(56)]** evaluated the fracture resistance of endodontically treated teeth restored with posterior direct composite (PRC) resin, bulk-fill composite resin, dual-cure composite (DCC) resin, and short fiber-reinforced composite (SFC) resin material. Ninety sound maxillary premolar teeth were divided into 6 groups which comprised 15 teeth each. Group I

was a negative control group where neither cavity preparation nor root canal treatment was done on the specimen. Group II was named positive control group as it was left unrestored after mesio-occluso-distal (MOD) preparation and root canal treatment. Groups III to VI were filled with PRC, bulk-fill composite, DCC, and SFC, respectively, and subjected to fracture testing in a universal testing machine. After statistical analysis, it was seen that group VI had increased mean fracture resistance as compared to other groups. It was concluded that short fiber-reinforced composite proved to have superior properties that other experimental groups and hence can be used as a core build-up material.

33. **Fráter M (2021)[(57)]** evaluated the fracture-behavior, survival and marginal-microgaps within the root-canal of immature anterior teeth restored with different fiber-reinforced post-core composites (FRCs). 180 bovine-incisors were randomly divided into 6 groups ($n = 30$). One group served as control (group 6). The rest of the teeth were prepared to an internal diameter of 1.6 mm and the apex was sectioned. After application of an MTA-plug, teeth were restored with FRC materials: Group 1: Bioblock technique with short fiber-reinforced composite (SFRC); Group 2: Bioblock technique with flowable SFRC; Group 3: Individually-made FRC post; Group 4: Conventional FRC post; Group 5: dual-cure core build-up composite. After restorations were completed, teeth ($n = 5$/group) were sectioned and then stained. Specimens were viewed under a stereo microscope and the percentage of microgaps within the root-canal was calculated. Fatigue-survival was measured using a cyclic-loading testing machine in the rest of the specimens. Flowable SFRC application in the root-canal (Group 2) did not differ from intact-teeth regarding fatigue-survival ($p > 0.05$). The rest of the groups produced significantly lower survival ($p < 0.05$) compared to intact-teeth. Post/core restorations made from conventional FRC post (Group 4) exhibited a high number of microgaps (38.3%) at the examined interphase in the root-canal. It was concluded that the restoration of immature incisors with the use of flowable SFRC as post-core material displayed promising performance in a matter of fatigue-resistance and survival.
34. **Silva CF, Martins VM, de Paula Melo A, Martins LC, Santos-Filho PC (2021)[(58)]**evaluated the influence of different composite resin in the customization of glass fiber posts (GFPs) on bond strength and failure mode.Thirty bovine roots were selected. The wall roots were reduced so that each wall had a minimum dentin

thickness of 1 mm. Thirty GFPs were divided into three groups ($n = 10$), which received different types of customization. The first had the GFP relined by bulk-fill flowable composite resin (BF), the second group had the GFP customized by conventional regular composite resin (CR), and the third group was cemented with dual resin cements (DRC), without relining. The root were sectioned, resulting in two 1.0-mm thick slices from cervical root regions only and push-out bond strength test was performed (EMIC, Universal testing machine). To determine failure mode, a stereomicroscope was used at ×40 magnification, with a 2.5D analysis.Data were analyzed using two-way ANOVA ($\alpha = 0.05$) and Tukey's test. BF (9.08 ± 1.9) and CR (9.17 ± 3.00) did not show a statistically significant difference ($p = 0.961$), regarding the bond strength test values. However, there was a statistically significant difference between DRC (5.44 ± 1.89) and the others ($p < 0.05$). BF (66.66%) and the CR group (47.61%) presented a predominantly failure mode type 6: mixed between resin cement and composite. While the highest failure index of the DRC group was type 2: adhesive between resin cement and dentin (47.61%).It was concluded that bulkfill can be an alternative for the customization of fiber posts, since it presented a similar behavior to the established technique with conventional composites.

35. **Khurana D, Prasad AB, Raisingani D, Srivastava H, Mital P, Somani N (2021)[(59)]** compared the resistance to fracture in maxillary incisors which were fractured in two different oblique patterns and then were re-attached and reinforced using anatomic fiber-reinforced composite (FRC) post – Ribbond and Everstick post. This study simulated a clinical scenario of coronal fracture of a tooth and concluded that these techniques and materials could be used for successful management of such cases.
36. **Säilynoja E, Garoushi S, Vallittu PK, Lassila** L **(2021)[(60)]**investigated specific physical and handling properties of new experimental short-fiber-reinforced DC resin composites (SFRCs) in comparison to different commercial, conventional DC materials (e.g., Gradia Core, Rebilda DC, LuxaCore Z, and Visalys®CemCore). Degree of monomer conversion (DC%) was determined by FTIR-spectrometry using either self- or light-curing mode. The flexural strength, modulus, and fracture toughness were calculated through a three-point bending setup. Viscosity was analyzed at room (22 °C) and mouth (35 °C) temperatures with a rotating disk rheometer. The surface microstructure of each resin composite was examined with scanning electron microscopy (SEM). Data were statistically analyzed with analysis

of variance ANOVA ($p = 0.05$). The curing mode showed significant ($p < 0.05$) effect on the DC% and flexural properties of tested DC resin composites and differences were material dependent. SFRC exhibited the highest fracture toughness values and LuxaCore showed the lowest values among the tested materials ($p < 0.05$). After light curing, Gradia Core and SFRCs showed the highest flexural properties ($p < 0.05$), while the other resin composites had comparable values. It was concluded that the novel DC short-fiber-reinforced core build-up resin composite demonstrated super fracture toughness compared to the tested DC conventional resin composites.

37. **Iwasaki T, Kamiya N, Hirayama S, Tanimoto Y (2022)[(61)]** conducted an in vitro study to investigate the mechanical behavior of commercially available bulk-fill and conventional flowable resin composites using the dynamic micro-indentation method. The effect of inorganic filler content on mechanical properties was also assessed. Weight percentages of the inorganic filler in the resin composite were measured using the ashing technique. The results showed that dynamic hardness and elastic modulus tended to increase with inorganic filler content. Furthermore, the differences in mechanical properties between top and bottom surfaces were less pronounced in bulk-fill flowable resin composites compared with conventional flowable resin composites. It was concluded that the mechanical properties of bulk-fill flowable resin composites are affected by filler content. Moreover, bulk-fill flowable resin composites have a higher polymerization depth than conventional flowable resin composites when sample thickness is 4 mm.
38. **Gallicchio V, Lodato V, Santis RD, Rengo S (2022)[(62)]** compared the fracture strength and failure modes of endodontically treated premolars restored with compact and hollow composite posts subjected to cyclic fatigue. Three type of endodontic posts, a carbon fiber hollow post, a glass fiber hollow post and a compact glass fiber post were investigated. Mechanical properties of these posts were assessed through bending tests. Teeth were subjected to fatigue cycling and the strength of restored teeth was detected through static tests. Failure modes were investigated through optical and scanning electron microscopy. Results show that composite posts increase the mechanical stability by more than 100% compared to premolars restored with particulate composite. Carbon fiber posts retain the highest strength (1467 N ± 304 N) among the investigated post and core restoration, but an unfavorable type of fracture has been observed, preventing the tooth re-treatment. Instead, more compliant posts

(i.e., glass fiber reinforced composite, providing a strength of 1336 N ± 221 N), show a favorable mode of fracture that allows the re-treatment of teeth in the case that failure occurs.It was concluded that glass fiber hollow posts show a good trade-off between strength and a favorable type of fracture.

39. **Attik N, Colon P, Gauthier R, Chevalier C, Grosgogeat B, Abouelleil H (2016)[(63)]** evaluated *in vitro* the mechanical, biological, and polymerization behavior of a flowable bulk-fill composite with fibers as a dispersed phase - EverX Flow™ (GC Corporation) (EXF), one conventional bulk-fill composite (Filtek™ Bulk Fill Posterior Restorative, 3 M (FBF)), and one flowable bulk composite without fibers (SDR® flow+, Dentsply (SDR)) were tested. The results showed statistically higher Vickers hardness and flexural modulus than EXF and SDR. However, EXF showed statistically higher K_{IC} than FBF and SDR. EXF had the statistically highest shrinkage stress values and FBF the lowest. Archimedes volumetric shrinkage showed significantly lower values for FBF as compared to the other two composites. Slight cytotoxic effect was observed for the three composites at day one. An enhancement of metabolic activity at day 5 was observed in cells treated with EXF extracts. This led to the conclusion that EXF had a significantly higher fracture toughness validating its potential use as a restorative material in stress bearing areas. EXF showed higher shrinkage stress values, and less cytotoxic effect. Fiber reinforced flowable composite is mainly indicated for deep and large cavities, signifying the importance for assessing its shrinkage stress and biological behavior.
40. **Abdelwahed AG, Essam S, Abdelaziz MM (2022)[(64)]** investigated the marginal adaptation and depth of cure of a flowable bulk-fill giomer (BEAUTIFIL Flow Plus X [BFP]), a flowable bulk-fill resin composite (PALFIQUE BULK FLOW [PBF]) bulk-fill resin composite, a packable bulk-fill giomer (BEAUTIFL-Bulk Restorative [BBR]), and two packable bulk-fill resin composites (X-tra fil [XF]) and (Filtek™ One Bulk Fill Restorative [FOB]). They found that regarding marginal adaptation, there was no significant difference between different groups before ($p=0.398$) and after ($p=0.644$) thermocycling. Within all groups, there was a significant decrease in marginal adaptation after thermocycling ($p<0.001$). Regarding the depth of cure, all restorative materials achieved the required 0.8 bottom-to-top ratio. There was a significant difference between different groups ($p<0.001$). The highest value was found in BFP group (0.97±0.02), while the lowest value was found in BBR group

(0.81±0.11). They concluded that the marginal adaptation and depth of cure of bulk-fill giomer restorative materials are acceptable. Therefore, their use in restoration of 4-mm deep class II cavities is appealing.

MATERIALS & METHOD

The present in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics, Babu Banarasi Das College of Dental Sciences, Lucknow in Collaboration with Central Institute Of Plastic Engineering And Technology, Lucknow.

Study Subjects

Thirty single rooted permanent human maxillary central incisor teeth

TABLE-1 MATERIALS AND ARMAMENTARIUM

1) For Sample preparation, Endodontic treatment:

S. No.	Materials & Armamentarium	Manufacturer
1.	Ultrasonic Scaler with tips	Coltene, Switzerland
2.	Straight hand piece	NSK, Japan
3.	Micro motor (Slow Speed)	Marathon, India
4.	Diamond disc & Mandrel	Shofu, Japan
5.	K-files (ISO #6,8,10,15,20,25)	Dentsply, India
6.	Protaper gold rotary files 21mm size (Sx,S1,S2,F1,F2)	Dentsply, India
7.	17% Ethylenedieamine tetra acetic acid (EDTA) solution	Ammdent, India
8.	3% Sodium hypochlorite (NaOCl)	Vishal Dentocare Pvt Ltd , India
9.	Normal Saline (0.9%w/v NaCl)	SPPL, India
10.	Disposable syringe of 5ml	Dispo Van, India
11.	30 gauge side vented needle	Oro, India
12.	Paper point	Dentsply India
13.	Endo block	API, U.S.A.
14.	Gutta Percha points (#F2)	Meta Aurum Pro, India
15.	AH Plus sealer	Dentsply, India
16.	Modelling Wax	Pyrex, India
17.	Silicone impression material	Zeta plus, Turkey
18.	Surgical blade #12	First Care Pvt Ltd, India
19.	Cold cure acrylic resin	DPI, India
20.	Polyvinyl chloride sheet	Supertek, India

21.	Digital calliper	Hoover, India
22.	Thermovacuum machine	Easy Vac, India
23.	Thermoplastic vacuum sheets	3A Medes, India

2) For Post Space Preparation, Placement And Core Buildup

S. No.	Materials & Armamentarium	Manufacturer
1.	Peeso Reamers (#1- 4)	Mani, India
2.	Fiber reinforced composite post	Ribbond, USA
3.	37% Phosphoric acid	Thixoetch, India
4.	Bonding agent (One coat bond)	Coltene, India
5.	Curing Light	Woodpecker, China
6.	Composite Restoration Instrument	GDC, India
7.	SDR flow plus	Dentsply, USA
8.	Beautifill bulkfill	Shofu, India
9.	Tetric N flow bulkfill	Ivoclar-Vivadent, India

3) For Crown Preparation, Cementation & Testing

S. No.	Materials & Armamentarium	Manufacturer
1.	SS white burs	New Jersey,USA
2.	PFM crown	Panna Dental, India
3.	Rely X luting cement	3M ESPE, India
4.	Instron Universal Testing Machine	Instron Industries, USA

Sample preparation

A total of 30 single rooted permanent human maxillary central incisor were selected according to inclusion and exclusion criteria from the Department Of Oral And Maxillofacial Surgery, Babu Banarasi Das College of Dental Science, Lucknow. The collected teeth were autoclaved, cleaned using ultrasonic scaler and then stored in water until further use.

Preoperative radiographs were taken in mesiodistal and buccopalatal direction to evaluate the following inclusion & exclusion criteria to select the teeth:

INCLUSION CRITERIA

Completely developed single rooted human permanent maxillary central incisor teeth with straight and single canal (one orifice and one foramen) determined radiographically.

EXCLUSION CRITERIA

1. Teeth with any crack, caries or calcification.
2. Teeth with any developmental anomaly.
3. Teeth with any restoration.
4. Endodontically treated teeth.

Standardization of teeth

The length of the crown and the root as well as the faciopalatal and mesiodistal width were measured at the cementoenamel junction (CEJ) with a digital calliper (Hoover, India). The crown length was confined to 10 ± 1.75 mm, and the root length was confined to 13 ± 1.75 mm. The faciopalatal and mesiodistal width at CEJ was confined to 6.75 ± 0.25 mm and 6.25 ± 0.25 mm, respectively.

Simulation of pdl ligament

The samples were dipped in melted wax 2 mm below the CEJ to produce a 0.2 -0.3mm layer to simulate the thickness of the periodontal ligament. The specimens were then embedded vertically in self cure acrylic resin which was poured into polyvinyl chloride (PVC) sheets which were molded to form cylinders with a dimension of 25 mm diameter and 40 mm height. Following resin polymerization, the teeth were retrieved from the acrylic resin and the wax was removed. Consequently, the spaces of the wax were filled with the polyvinyl silicone impression material (Zeta plus, Turkey) to imitate periodontal ligament. The teeth were then inserted back into the sockets and excess material was removed using a blade #12.

Endodontic treatment

A transparent matrix was made over the crown by using a thermovacuum machine to record the dimensions of the crown, to be used for the composite core buildup. The crowns were then decoronated 2mm above cementoenamel junction to provide a uniform ferrule of 2mm height using mandrel and disk. Using a 10K file (Dentsply) the patency of the canal was verified and working length was determined. File was introduced inside the canal till it was radiographically visible at the apex keeping the stopper 2mm above the CEJ (as the coronal reference point). From that length 0.5 mm was substracted and taken as working length. Hand filing till #25K was done. The cleaning and shaping was continued using crown down technique and the root canals for all the teeth were prepared to a file size of F2 of Protaper gold rotary file system setting the torque to 312gcm and speed to 300 rpm as per manufacturer's recommendation. For irrigation 3ml of 5.25% sodium hypochlorite was used between each file instrumentation. For the removal of smear layer 5ml of 17% EDTA was flushed onto the canal and the canal was finally rinsed with 10 ml of normal saline. The canal was then dried with paper points and with the help of a lentulospiral the sealer was placed inside the canal (AH Plus). The obturation was done with single cone insertion method using using #F2 GP point (Dentsply).

A post space preparation of 1.1 mm thickness was made using size #4 peeso reamer leaving 5mm of gutta percha to provide apical seal for all groups. The post space was then etched with 37% phosphoric acid (Thixoetch) for 15 seconds and rinsed with water. The canal was air dried and a bonding agent (One coat bond) was applied inside the post space using an applicator tip and light cured for 20seconds.

The samples were divided into three groups with 10 samples in each group based on the core buildup material.

Group I - Tetric N flow (10 teeth)

Group II - Beautifil bulk flow (10 teeth)

Group III - SDR flow plus bulkfill composite resin (10 teeth)

Table 2 : Core buildup materials used and their compositions

Manufacturere's Name	**Composition**	**Weight%/volume%**
Tetric N Flow Ivoclar Vivadent; Schaan Liechtenstein	• Dimethacrylates (Bis GMA, Bis EMA, UDMA) • Barium glass • Yetterbium trifluoride • Mixed oxides • Prepolymers • Additives	81/61

	• Catalysts • Stabilizers • Pigments	
SDR Flow Plus Dentsply; Konstaz;Germany	• Modified UDMA • EBPADMA (Ethoxylated bisphenol A dimethacrylate) • TEGDMA • Ba-Al-F-B Silicate glass • Sr-Al-F Silicate glass • Camphoroquinone • Photoaccelerator • BHT • UV stabilizer • Titanium dioxide • Iron oxide piments • Fluorescent agent	68/45
Beautifill Shofu; USA	• Bis-GMA • UDMA • Bis-MPEPP • TEGDMA • Fluoro-silicate glass	87/74.5

GROUP 1

Fiber reinforced composite post (Ribbond) was wetted with the bonding agent placed on a glass slab and luted with Tetric N Flow resin cement and condensed into the post space in increments of 4mm and light cured for 20 seconds. The rest of the post space was again filled up in 4mm increments of ribbond wetted in bonding agent and luted with flowable composite and light cured. The resin cement was also packed inside the transparent crowns which were earlier prepared and light cured 20 seconds from each side mesial, distal, buccal and lingual.

GROUP 2

Fiber reinforced composite post (Ribbond) was wetted with the bonding agent placed on a glass slab and luted with Beautifill bulk fill resin cement and condensed into the post space in increments of 4mm and light cured for 20 seconds. The rest of the post space was again filled up in 4mm increments of ribbond wetted in bonding agent and luted with flowable composite and light cured. The resin cement was also packed inside the transparent crowns which were earlier prepared and light cured 20 seconds from each side mesial, distal, buccal and lingual.

GROUP 3

Fiber reinforced composite post (Ribbond) was wetted with the bonding agent placed on a glass slab and luted with SDR Flow Plus resin cement and condensed into the post space in increments of 4mm and light cured for 20 seconds. The rest of the post space was again filled up in 4mm increments of ribbond wetted in bonding agent and luted with flowable composite and light cured. The resin cement was also packed inside the transparent crowns which were earlier prepared and light cured 20 seconds from each side mesial, distal, buccal and lingual.

CROWN PREPARATION

Preparation of all teeth was performed to receive porcelain fused to metal crowns with shoulder margins of 1.1 mm circumferentially. Margins of all the groups were placed 2 mm apical to the level of the core material to attain the ferrule effect. The crowns were cemented using resin modified glass ionomer cement which was mixed according to manufacturers recommendation and light cured for 20 seconds from each side mesial, distal, buccal, palatal. The excess cement was trimmed off.

FRACTURE RESISTANCE TEST

Each specimen was held in place for testing in a special jig with its long axis inclined facially, at an angle of 135^0 and subjected to a load on a universal testing machine at a crosshead speed of 0.5 mm/minute until failure occurred.

FLOWCHART OF METHODOLGY

30 maxillary central incisors

↓

Decoronated 2mm above CEJ

↓

Working length determination

↓

Endodontic treatment upto hand file size #25K and rotary file size #F2(Protaper Gold)

↓

Post space preparation

↓

Table 3 : Group Allocation

GROUPS	NO. OF SAMPLES	CORE MATERIALS
GROUP A	10	Tetric N Flow
GROUP B	10	Beautifill
GROUP C	10	SDR Flow Plus

Post cementation and corebuildup

↓

Crown preparation and cementation

↓

Measurement of fracture resistance

↓

Results recorded and compared

Statistical Analysis

The results obtained were tabulated and subjected to One-way ANOVA and Tukey's post-hoc using Statistical Package for Social Sciences (SPSS, V 16.0) package with significance value (p) kept at <0.05.

Fig 1 : Teeth collected for experiment

Fig 2 : Autoclave

Fig 3 : Storage of sterilized teeth in normal saline

Fig 4 : Biosonic scaler

Fig 5 : Thermovacuum machine

Fig 6 : Materials for mold preparation

6 (a). Polyvinyl chloride sheet

6 (b). Modelling wax

6 (c). Self Cure Powder

6 (d). Self cure liquid

Fig 7 : Materials for simulation of pdl space

Fig 8: Insertion of teeth into the prepared mold

Fig 9 : Removal of excess material

Fig 10 : Equipments for Decoronation of teeth

Fig 11: Decoronation of tooth

Fig 12:Armamentarium for shaping of root canal

Fig 13 : Armamentarium for irrigation

13 (a). Sodium hypochlorite

13 (b). side vented needle

13 (c). 3ml syringe

13 (d). Normal saline

13(e). chlorhexidine

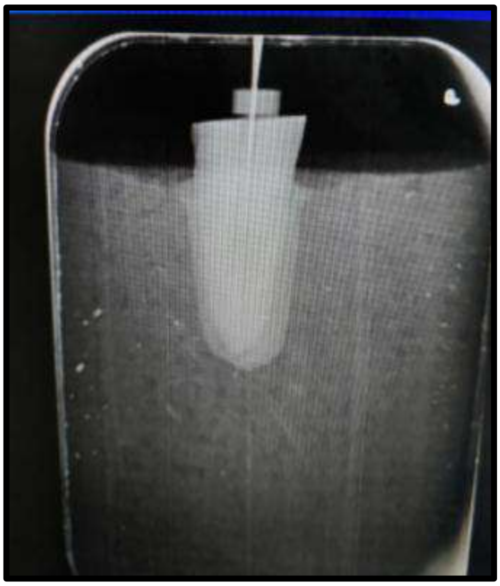


Fig 14 : Radiograph demonstration of working length

Fig15: Armamentarium for obturation

15 (a). Glass slab

15 (b). tweezer

15 (c). paper point

15 (d). Plastic splatula

15 (e). AH plus sealer

15 (f). Protaper gutta percha points

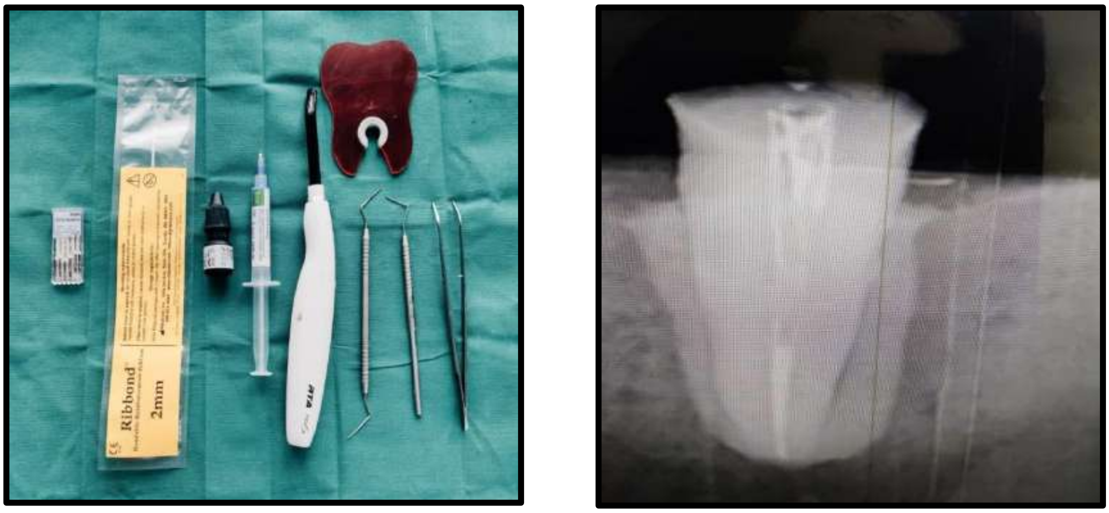


Fig 16 : Armamentarium and radiographic evaluation of obturation , post space preparation and placement

16 (a). peezo reemer

16 (b). Ribbond post

16 (c). bonding agent

16 (d). etchant

16 (e). curing lamp

16 (f). Williams probe

16 (g). condensor

16 (h). tweezer

Fig 17 : Core buildup materials

17 (a). SDR Flow Plus

17 (b). Tetric N Flow

17 (c). Beautifill

Fig 18 : Wetting the post with bonding agent

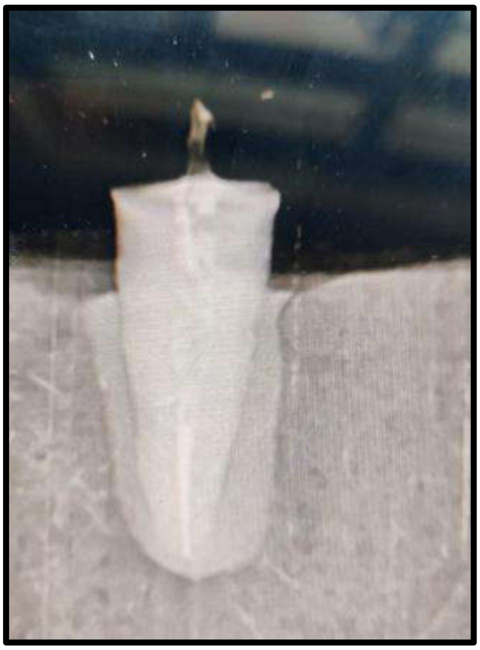
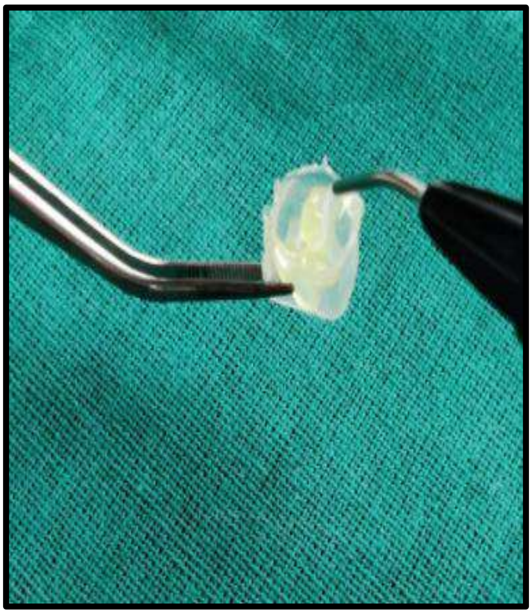


Fig 19 : Curing and radiographic evaluation of post placement with bulkfill materials placed in increments of 4mm and cured



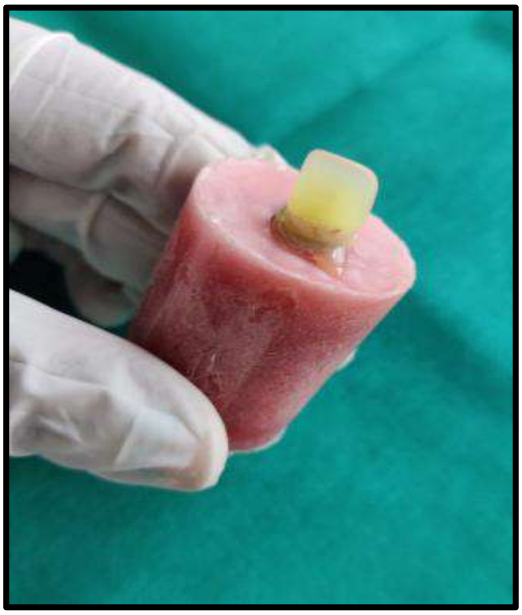


Fig 20 : Core placement using transparent crowns and sample after light cure

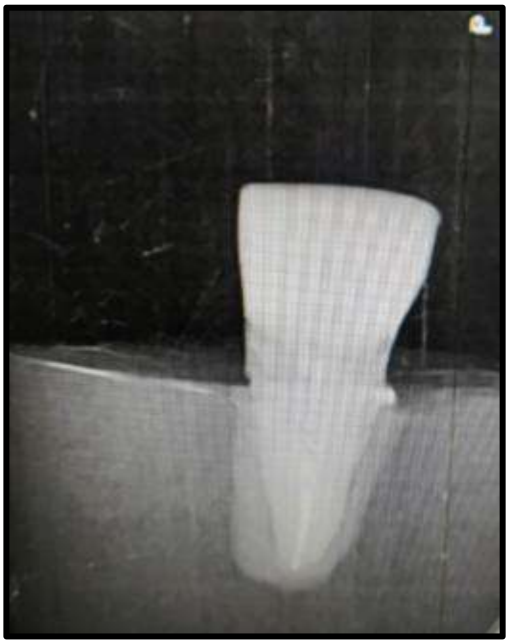


Fig 21 : Radiographic assessment of post and core for different groups

22:Armamentarium for crown preparation and placement

22 (a). dual cure resin cement

22 (b). Plastic spatula

22 (c). mixing pad.

22 (d). crown preparation burs

Fig 23:Crown preparation with shoulder of 1.10mm

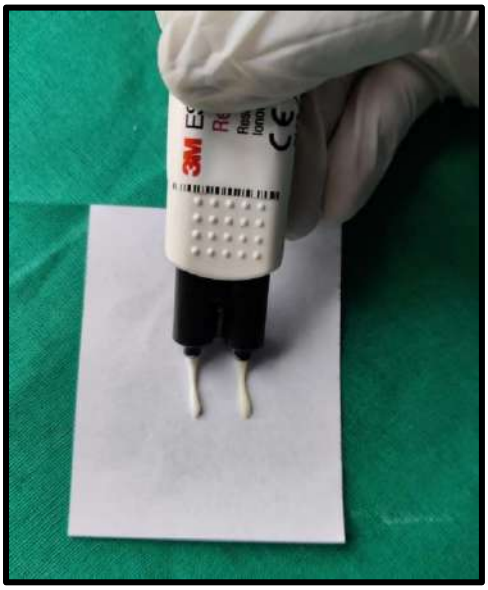


Fig 24 : Crown luting cement

Fig 25 : Luting of crown and light curing

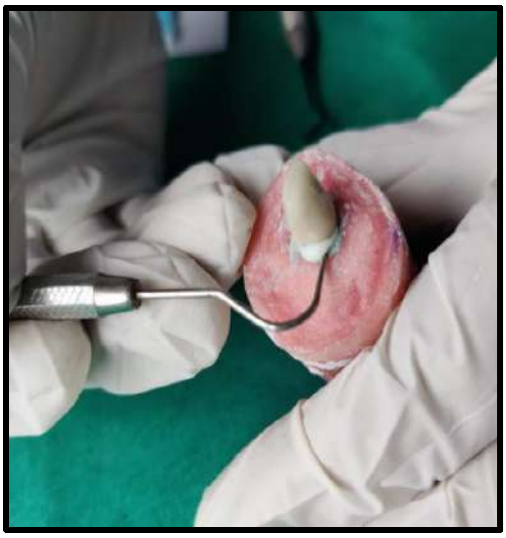


Fig 26 : Removal of excess cement

Fig 27 : Prepared samples of Tetric N Flow, Beautifill, SDRFlow Plus

Fig 28 : Universal testing machine

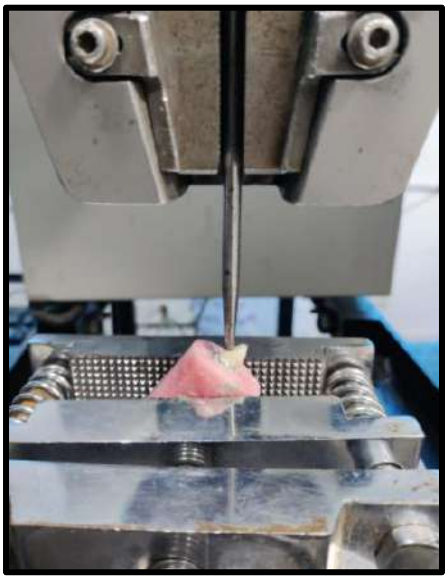


Fig 29 : Placement of samples at 135º angulation for testing

OBSERVATION AND RESULTS

The test used to determine the results for this in vitro study was fracture resistance test. This test was conducted at Central Institute of Petrochemicals Engineering and Technology, Lucknow. The fracture resistance value for three Bulkfill flowable core buildup materials – Tetric N Flow, Beautifill, SDR Flow Plus was determined and their intergroup comparisons were done.

Table 4 : Maximum compressive load values for different groups (Newton)

Group-1 Tetric N Flow	Group-2 Beautifill	Group-3 SDR Flow Plus
166.75	**87.49**	**192.84**

- The table showing the maximum compressive load in Newton for different groups
- The mean compressive load was 166.75 (N) in group 1
- The mean compressive load was it is 87.49 (N) in group 2
- The mean compressive load was 192.8 4 and in group 3

Table 5 - Mean, SD, Maximum and Minimum of Maximum compressive load of different groups

Parameter	Group-1 Tetric N Flow	Group-2 Beautifill	Group-3 SDR Flow Plus
N	10	10	10
Mean (N)	166.75	87.49	192.84
Max-Compressive load SD	4.28	7.13	12.24
Minimum	159.29	75.95	174.44
Maximum	173.74	97.43	205.85

- The above table showing the mean, SD, maximum and minimum of Maximum Compressive load of different groups
- The mean and SD of maximum compressive load was 166.75 and 4.28 in Newtons maximum load was 173.74 (N) and minimum was 173.74 (N) in group 1 (Tetric N Flow)

- The mean and SD of maximum compressive load was 87.49 and 7.13 in Newton maximum load was 97.43 (N) and minimum was 75.9 5 (N) in group 2 (Beautifill)
- The mean and SD of maximum compressive load was 192.84 and 12.24 in Newtons maximum load was 205.85 (N) and minimum load was 174.44 (N) in group 3 (SDR Flow Plus)

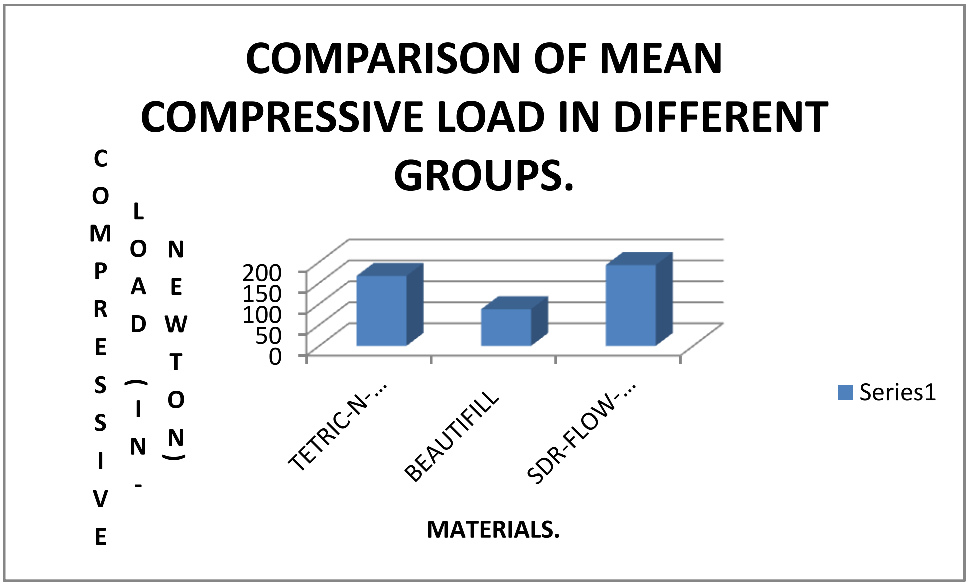


Table 6 : Analysis of variance of maximum compressive load in different groups (ANOVA table)

Source of variation	Sum of Square	Degree of freedom	Mean Sum of V Squares	'F'	'P'
Between Groups	60199.3965	2	30699.6982	F = 412.15	p< 0.00001 (Sig)
Within Groups	1971.8224	27	73.0305		
Total	62171.2189	29			

- Since 'F' value was found significant, P < 0.00001. Hence maximum compressive load differ significantly in different groups.
- It was found maximum in group 3 (SDR Flow Plus) and minimum in group 2 (Beautifill)

Table 7 : Comparison of maximum compressive load in group 1 (Tetric N Flow) and group 2 (Beautifill)

	Group 1(Tetric N Flow)	Group 2 (Beautifill)
N	10	10
Mean Compressive load (N)	166.75	87.49
SD	4.28	7.13
Min - Max	159.29-173.74	75.95-97.43

By Tukey test : P < 0.00001 (significant)

- Mean compressive load was 166.75 with SD 4.28 in Newton in group 1
- Mean compressive load was 87.49 with SD 7.13 in Newton in group 2
- Mean compressive load was significantly more in group 1 then group 2 to (p < 0.00001, Significant)

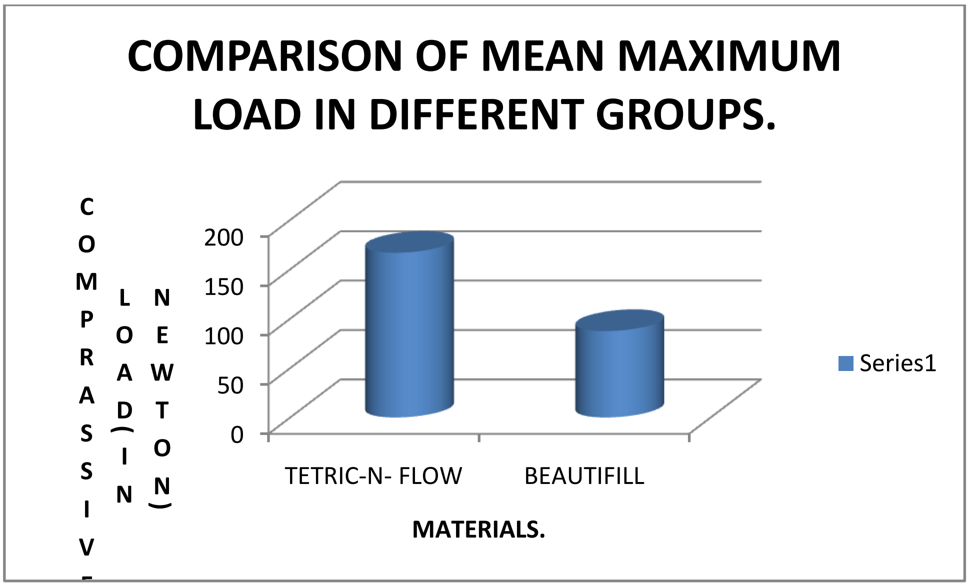


Table 8 : Comparison of maximum compressive load in group 1 (tetric N Flow) and group 3 (SDR Flow Plus)

	Group 1(Tetric N Flow)	Group 3 (SDR Flow Plus)
N	10	10
Mean (N)	166.75	192.84
SD	4.29	12.24
Min - Max	159.29-173.74	174.44-205.85

By Tukey test : P < 0.00001 (significant)

- The mean compressive load was 166.75 (N) with SD 4.29 in group 1 (Tetric N Flow)
- The mean compressive load was 192.8 4 (N) with SD 12.24 in group 3 (SDR Flow Plus)
- The mean compressive load was significantly more in group 3 than group 1 (p < 0.00001, significant)

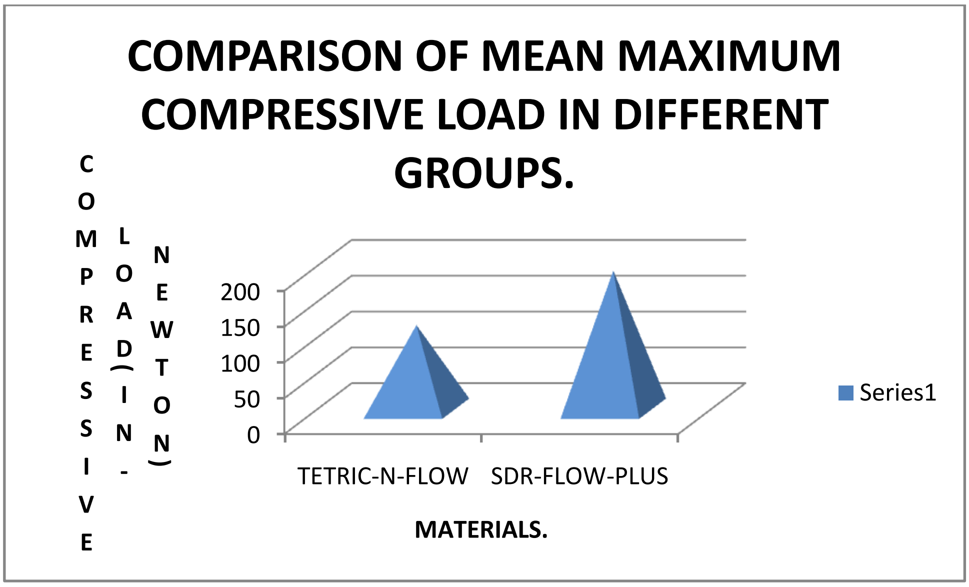
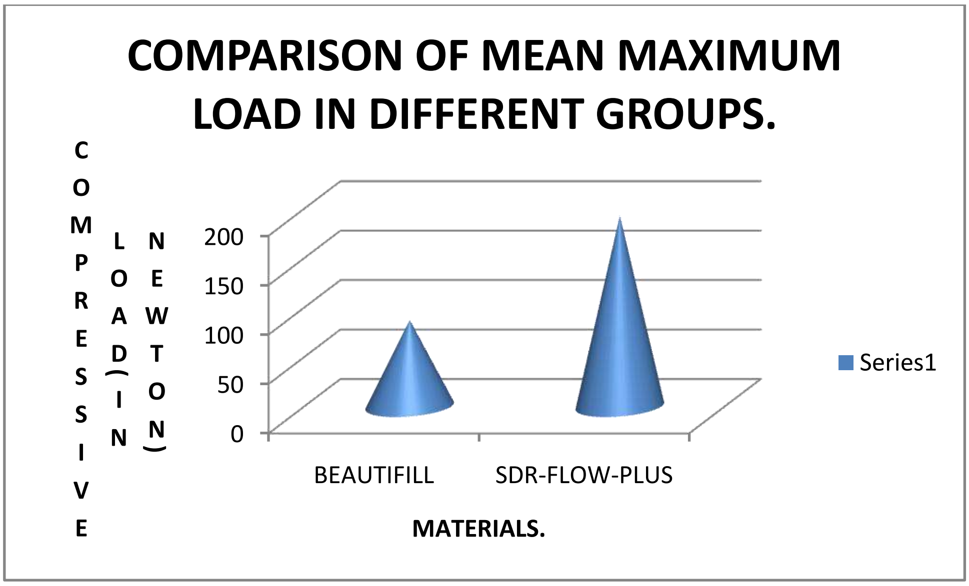


Table 9 : Comparison of maximum compressive load in group 2 (Beautifill) and group 3 (SDR flow plus)

	Group 2(Beautifill)	Group 3 (SDR Flow plus)
N	10	10
Mean (N)	87.49	192.84
SD	7.13	12.24
Min - Max	75.95-97.43	174.44-205.85

By Tukey test : P < 0.00001 (significant)

- The mean compressive load was 87.49 with SD 7.13 in Newton in group 2 (Beautifill)
- The mean compressive load was 192.84 with SD 12.24 in Newton in group 3 (SDR flow Plus)
- The mean compressive load was significantly more in group 3 than group 2 (p < 0.00001, significant)



Result

Maximum compressive load

Group 3 > Group 1 > Group 2

Maximum compressive load was in group 3 (SDR flow Plus) then in group 1(tetric N flow) and minimum in group 2 (beautifill)

DISCUSSION

Endodontic treatment involves removal of infected and necrotic tissue and cleaning and obturation of the root canal space.(65) Continuous development in the field of endodontic and restorative procedures has led to tooth retention and longevity. However, it has been noticed that a sufficient number of endodontically treated teeth require intraradicular devices to restore their function.(66) So the question arises as to when are these intraradicular devices required?

According to *Cohen BI et al.*(67) when there is not sufficient amount of remaining tooth structure to retain the core – a post is indicated. This post should provide adequate retention and resistance form to the displacement of core material. According to *Fernandes AS et al.*(68) selection of post depends on a variety of factors. These factors include tooth anatomy, position of tooth in the arch, root length, root width, canal configuration, functional requirements of the tooth, torqueing forces, stresses, development of hydrostatic pressure, post design, post material, material compatibility, bonding capability, core retention, retrievability, esthetics and crown material.

The history of post dates back to 1700s, when *Fauchard*(69) inserted wooden dowels in root canals to aid for crown retention. But it was noticed that over a period of time, the wood would expand due to moisture in the environment and unfortunately, lead to root fracture. In 1800s, the use of intra radicular devices was limited due to failure of endodontic therapy in that era.(70)In 19th centuryagain, several dentists used wooden posts but a few dentists reported the use of metal posts which was favoured by *Black i*.(71) In this, a screw was passed through a gold lined root canal to secure a porcelain faced crown. In mid *1800s, Clark*(72)introduced a device that allowed drainage from the apical area and this device was considered quite practical for its time. In 1878, Richmond crown was introduced(73). It was a screw retained crown with a threaded tube in the canal. Later, modifications were made in 1957 by *Demas NC et al.* and in 1958 by *Hampson EL et al.*(75)which eliminated the threaded tube and redesigned it to a one piece dowel and crown. However, because of their impractical nature, they lost their popularity. This was became very obvious when divergent paths of insertion for remaining tooth structure and post space existed mostly for abutments of fixed partial denture. Also, when crowns and FPD required replacement and removal, one piece dowel crowns created problems. All of these difficulties led to the development of post and core restorations to be treated as separate entities in which artificial crowns were cemented over the core and remaining tooth structure.

Posts can be fabricated from a variety of materials that include cast gold, stainless steel, titanium and titanium alloys, goldplated brass, ceramic and fiber reinforced polymers. However, according to *Deutch et al.*[75]for a post to achieve optimum results it should be made up of a suitable material. This material should have properties similar to that of dentin, should be biocompatible, non corrosive and bond well to the tooth structure. According to *Fredriksson M et al*.[76]the post material should act as a good shock absorber, transferring only limited stresses to the residual tooth structure. Cast gold post and cores had a 90.6% clinical success rate in 6 years in retrospective studies but their high cost became matter of concern. Stainless steel posts have been used for a long time as a prefabricated post but show nickel sensitivity. Also, brass posts and stainless steel posts depicted corrosive behaviours. Pure titanium posts had low fracture strength and tended to break easily than stainless steel posts during removal in retreatment cases. Most titanium posts showed density similar to gutta percha and were difficult to identify on radiographs. Ceramic posts showed good physical properties like flexural strength and toughness and were also esthetically pleasing under all ceramic crowns. However, two in vitro studies reported their poor resin bonding capability to dentin under fatigue loads.[77] Another new post that came into study was the fiber reinforced post. It was made up of carbon or silica fibers embedded in a matrix of polymer resin. These fibers range from 7 to 10 micrometers in diameter and are available in different configurations – longitudinal, woven, braded. Along with these posts fiber reinforced composite posts were also introduced. The most common fibers used in clinical practice are Ultrahigh molecular weight polyethylene fibers - Ribbond (Ribbond), Connect(Kerr), Glass Fibers- GlasSpan (GlasSpan) and fiber Splint ML(Polydentia), Fibers preimpregnated with resin Vectris (Vivadent), StickNet (StickTech) and FibreKor (Jeneric/ Pentron). In vitro studies showed that the strength of fiber posts was lower than that of cast metal post and cores. The rigid metal transferred lateral forces without distortion to dentin. This led to root fracture. Whereas the low flexural strength of fiber reinforced post (i.e between 1×10^6 - 4×10^6psi) measured closer to dentin (2×10^6psi) decreased the incidence of root fracture.[78] Also fiber reinforced posts bonded well with resin cements and resin based core buildup materials. In vivo SEM study also showed that fiber reinforced posts showed a clear formation of a hybrid layer, resin tags and an adhesive lateral branch when they were bonded to the dentin using composite core materials.[(79)] This successful bonding minimized the wedging effect of post and required less dentin removal for the accomodation of shorter and thinner posts which in turn lead to low susceptibility of tooth to fracture. Fiber reinforced composite posts allow good esthetics in visible areas of the mouth, donot corrode or provide metal allergies and can be easily removed in retreatment cases. A study on the fiber reinforced posts reported a failure rate of only 3.2% over a period of six years.[(80)] According to two retrospective studies of 4 years duration fiber reinforced posts delivered a 95% success rate.[(81)] Like the ceramic posts, these fiber reinforced posts are relatively new and less data is available on their long term clinical performance. Among these posts Ribbond is a relatively new post with a spectrum of 215 ultra high strength polyethylene fibers which exceed the break point of fiberglass. It has 117GPa coefficient of elasticity which makes it highly resistant to stretch and distortion. It has a lockstitch feature design and are easily manageable. Its lack of memory helps in layering of the fibers. It tucks inside the canal without rebounding. It has an added advantage that unlike Kevlar, it absorbs less moisture. It’s a highly retentive and passive posts. Its translucent fibers take on the color of the composite. This in turn leads to natural transmission of lights through the teeth and the crowns.

In relation to this literature, Studies on adhesive luting of fiber reinforced composite post date back to 1997.[(82)] Although various other materials have been used like zinc phosphate cement, polycarboxylate, Glass ionomer and RMGIC. Among these, the most traditional is Zinc phosphate. It has adequate physical properties, is inexpensive and easy to use. However, it lacked the ability of true adhesion and was soluble in the oral cavity. On the other hand, polycarboxylate provided a weak chemical bond to dentin and on cyclic loading it underwent plastic deformation. Glass ionomer cement provided a good fluoride releasing potential making it anticariogenic. But it also provided a weak chemical bond to dentin and according to *Matsua et al.*it was considered as a an unsuitable agent for luting of various posts since it took several days to months to reach its maximum strength value.[(83)] RMGIC were fluoride releasing, insoluble and provided good retention of post. But according to *Miller. t*his cement absorbs water and expands with time which leads to volumetric expansion of the cement and ultimately fracture of all ceramic crowns and also vertical root fracture.[84] *Duncan et al.* suggested that there is greater post retention when it is cemented with adhesive resin.[(85)] They have highest compressive strength values and lowest solubility in compsrison to all other cements. Although conventional, these studies are still continued to be studied in recent years. Since these posts provide esthetics as well as strength, they are considered as a viable option for cast post or prefabricated metal posts. Their modulus of elasticity similar to dentin so they proclaim to avoid root fracture. Also bonding of posts in the root canal turned into a more effective factor to reduce stresses in the canal and avoid root fracture. Further, this adhesive luting of post prevented decementation when compared to cemented posts. This turned out to be a major factor for post retention rather than the design of the post.

Placement of composites is technique sensitive and requires thorough light cure. If not cured properly, their longevity and function gets compromised. It requires to be placed in increments of atleast 2mm. Also inability to isolate the tooth and placement in increments may lead to inclusion of air bubbles which leads to their reduced mechanical properties and bond failure. With advances in the science of resin composites, a new type of composite were introduced called as the bulk fill composites. They had the tendency to be cured in increments of 4-5 mm. This reduced their chairside time. The bulkfill composites are available in two forms – flowable and packable. However there are just a few studies that provide reference to their use in canals as cements and core buildup materials. This study was undertaken to use bulkfill flowable materials inside the canal as cements and core buildup materials and the use of ribbond as the post material. The core materials used are SDR Flow Plus, Tetric N Flow and Beautifill. SDR flow plus is a new bulkfill flowable composite material that has been introduced by Dentsply in 2018. It is a new and advanced variant of conventional Surefill SDR which has increased filler particles that give it good mechanical properties and enhanced applications. It is compared with Tetric N Flow and Beautifill bulkfill,, another bulkfill flowable composites. Since there is no in vitro study done on these materials using Ribbond. This study was conducted to determine the fracture resistance of teeth afterwards.

This study takes place in vitro conditions. Since, according to *CRIS guidelines (Checklist For Reporting In Vitro Studies)* in vitro studies act as a platform for us where we can create, compare, and check the materials used in dentistry prior to their clinical use. These researches form an integral part of decision making since it guides the clinician about the physio – mechanical and biological properties of various dental materials and hard dental tissues. Also it is found that 82% articles in The Journal Of Conservative Dentistry and leading articles are in vitro studies. Endodontics also played a substantial role in this regard. (International Endodontic Journal surveyed 88%, Dental materials surveyed 98%, Journal of Endodontics - 65%, and Operative Dentistry - 74%). Also fracture load test is the most common in vitro test to measure the strength of a post and core design. Irrespective of it, being designed with a high standard deviation in respect of the loads measured. These tests cannot be performed clinically. Apart from this in vitro studies also reduce the expense of time, take place in a controlled setting and environment. Therefore, they reduce the risk of any bias and are easy to perform. It also helps the reader and clinician to analyse the variables which affect the outcome of the material and facilitating an evidence based practice. According to studies done by *Sturb et al.*[(87)]higher fracture resistance is noted in comparison to artificial roots. Although human teeth have a number of disadvantages, they are the preferred teeth for in vitro testing of post and cores. Therefore, they have been used in this study.

A sample size of 30 teeth was calculated based on study done by *Dayalan Subhash et. al.*[(88)]Assuming a pooled SD of 11.14 units, the new study would require a sample size of 10 for each group (ie: total sample of 30, assuming equal group size), to achieve a power of 99% and a level of significance of 1% (two-sided) for detecting a true difference in mean between the test and reference group of 27.248 units.

The tooth chosen were single rooted maxillary central incisor since they are the tooth that are more prone to fracture or trauma and require an esthetic treatment modality. The teeth were sterilized in an autoclave at 15 psi pressure and 121ºC temperature for 15 mins. This was done to prevent cross infection and provide safety. the feel and In a study by *Simarpreet V. Sandhu et al.*[(89)] it was also stated that the method of sterilization does not affect cutting characteristics of teeth. To prevent dessication, these teeth were then stored in normal saline.

For the standardization of teeth, the length of the crown and the root as well as the faciopalatal and mesiodistal width were measured at the cementoenamel junction (CEJ) with a digital calliper (Hoover, India). The crown length was confined to 10 ± 1.75 mm, and the root length was confined to 13 ± 1.75 mm. The faciopalatal and mesiodistal width at CEJ was confined to 6.75 ± 0.25 mm and 6.25 ± 0.25 mm, respectively based on studies done by *Monaco C et al.*[(90)]

The teeth were cut using a diamond disc 2mm above the CEJ in accordance to studies done by *Ng et al and Sorenson et al.*[(91)]It was said that a remaining crown structure of 2-3 mm is beneficial for increased fracture resistance of an endodontically treated tooth post and cores and complete crown prosthesis. To simulate the periodontal ligament space the teeth were dipped in melted wax 2 mm below the CEJ to produce a 0.2 -0.3mm layer to simulate the thickness of the periodontal ligament and the freedom of movement in it. The specimens were then embedded vertically in self cure acrylic resin which was poured into polyvinyl chloride (PVC) cylinders with a dimension of 25 mm diameter and 40 mm height. Following resin polymerization, the teeth were retrieved from the acrylic resin and the wax was removed. Consequently, the spaces of the wax were filled with the polyvinyl silicone impression material (Zeta plus, Turkey) to imitate periodontal ligament. The teeth were then inserted back into the sockets and excess material was removed using a blade #12. This arrangement mimicked human jaw in which teeth were placed in their respective bony sockets. This was done to simulate the clinical and oral parameters.

Since teeth that do receive a post are endodontically treated first, therefore endodontic treatment was performed on all the teeth. According to *Sareh habibzadeh et al.*[(92)]this endodontic treatment was mandatory since it results in small or negligible loss in tooth structure and produces reliable results in clinical conditions.

Crown down technique was used to do the biomechanical preparation in this study. This involved providing a continuously tapering funnel having widest diameter at the access cavity and narrowest at the apex. This had an added advantage of less preparation time, less extrusion of debris and better and deeper penetration of irrigants. Protaper gold file system has been used in the study since it provides a uniform canal preparation. There is also less chances of canal transportation, ledging, perforation, offer least resistance and follow the canal anatomy and curvatures. Irrigation of canal was done using EDTA and sodium hypochlorite since theu habe good antimicrobial properties and tissue dissolution properties. AH sealer which is also considered as the standard sealer is used in this study since it provides good radio opacity, mechanical properties, low polymerization shrinkage and less solubility. According to a study done by *Anuve Hrishi phukan,*[93] AH plus sealer provides higher bond strength to dentin since it reacts with exposed amino in collagenforming a covalent bond between them when the epoxide ring opens. After the obturation, the sealer in the canal was left to set for 48 hrs as this was its required setting time. To provide a guaranteed apical seal, the length of gutta percha is supposed to be between 3-6mm apically. Therefore, 5 mm of apical gutta percha was left and the remaining was removed from the canal using a peeso reamer. Also according to studies done by *Kantorowicz G.F*,[94] the recommended post should be atleast the same length of the crown which is being restored but if not possible, then the post should atleast extend to within 5mm of radiographic apex. Also guidelines for clinical success of post suggest that post length should be one half to two thirds of remaining root length. However, post length and depth are of less importance to avoid perforation. Instead the ferrule is more important in this regard. A post space preparation of 1.1mm was done which was in accordance to studies done by *Shillinburg HT et al.*[95]he stated the maximum post diameter for maxillary central incisor which was 1.5mm. In the present study fiber reinforced composite post - Ribbond is used which requires minimum post space preparation. The posts were then luted using respective resin cements. For a uniform core buildup that mimicked the previous crown structure, this resin cement was also packed inside the transparent crowns and light cured as was depicted in studies done by *Dayalan et al.*[96]After core builup was completed, crown preparation was done and a ferrule was provided since a ferrule increases the fracture resistance of endodontically treated teeth and reduces the stress within the tooth. It is considered crucial to to optimise the biomechanical behaviour of tooth. According to studies done by *Jelena and Juloski,*[97] a successful clinical outcome of an endodontically treated teeth depends on the post and core system used, the luting agent used and the crown type used. Therefore, a porcelain fused to metal crown is also provided in this study which provides esthetics and a reliable clinical outcome for anterior esthetic tooth restoration.

Each specimen was held in place for testing in a special jig with its long axis inclined facially, at an angle of 135^0. This angle was chosen since it mimicked the labio lingual inclination of maxillary central incisor tooth in class I occlusion. This arrangement of specimen was then subjected to a load on a universal testing machine at a crosshead speed of 0.5 mm/minute until failure occurred. This allowed time for force distribution from the point of application to test the fracture resistance using Universal Testing Machine.

In the present study, 3 different core buildup materials were tested for their fracture resistance values against a fiber reinforced composite post – Ribbond and it was observed that Group 3- SDR bulkfill composite resin showed the highest fracture resistance value. SDR FLOW Plus contains Modified UDMA,EBPADMA (Ethoxylated bisphenol A dimethacrylate),TEGDMA, Ba-Al-F-B Silicate glass, Sr-Al-F Silicate glass, Camphoroquinone, Photoaccelerator, BHT, UV stabilizer, Titanium dioxide, Iron oxide pigments and fluorescent agent. Among these, the modified UDMA is patented. It contains photoactive groups that control polymerization kinetics. Therefore, SDR Flow Plus is also referred to as the stress reducing resin. The enlarged depth of cure is attributed to the materials translucency. This can be done by a simple approach- reducing the filler amount since filler amount and translucency show a linear relation. The difference in refractive index of filler particles and resin matrix also affect the translucency of the resin. This governs the light transmission within the material. Similar refractive index between the components improve material translucency. SDR Flow Plus has fillers of more than 20µ dimension than other materials used in the study. Also this increased fracture resistance may be attributed to its low flexural modulus and slower rate of contraction. According to studies by *Marigo et al.* SDR Flow Plus reaches higher depth of cure(82% bottom to top) at 4mm when it was compared to conventional composites. According to *Miletic et al.* depth of cure at depth of 4mm is directly related to curing time expressed as microhardness since bottom to top was 80 % when it was light cured from 10-20 seconds. Also studies by *Hickel* revealed that *SDR Flow Plus* shows lowest shrinkage stress when compared to other bulkfill flowable composites.

In our study, Tetric N Flow group showed less compressive strength values which are consistent to the study done by *Austin* in which Tetric N Flow being a nanohybrid composite showed lower mechanical properties in comparison to Filtek bulkfill which was a microhybrid composite. It shows comparable compressive strength to Filtek bulkfill. higher fracture resistance can be credited to the fact that it has higher filler loading and lower nano dimensions. However their use in load bearing areas as core buildup materials is questionable.

Beautifill bulkfill showed the least fracture resistance value in our study. This value can be attributed to the fact that Beautifill bulk fill has a different resin composition of Bis-GMA, UDMA, Bis-MPEPP, and TEGDMA. This result was in contrast to study done by *O.H. Abdulhameed* in which its increased fracture resistance value was attributed to its higher percentage of filler loading (87% by weight,74.5% by volume). Beautifill bulkfill is a giomer i.e. a combination of glass ionomer and a polymer. It contains surface pre-reacted glass ionomer (S-PRG) filler particles within the resin matrix. It is considered as a true hybrid of composite resin and glass ionomer and therefore, the presence of glass ionomer is responsible for its weak compressive load values not making it a true bulkfill composite.

In relation to authors knowledge there is no previous study that compares these bulkfill flowable corebuildup materials with the fiber reinforced composite post - Ribbond post used. Therefore, further research and testing is suggested for the use of these flowable bulkfill composites as core buildup materials in determining the fracture resistance of endodontically treated maxillary incisors that are restored used a fiber reinforced composite post- Ribbond.

CONCLUSION

Our study reported that the maximum fracture resistance value of endodontically treated teeth restored with fiber reinforced composite post - Ribbond was observed using SDR Flow Plus followed by Tetric N Flow and least by Beautifill. Suggesting the use SDR Flow plus and Tetric N Flow as suitable core buildup materials. This study proves that bulkfill materials can also be used as luting agents apart from being used as core buildup materials. Beautifill bulkfill comprises of giomer technology making it a weak material to be used as corebuild up. Therefore, it should not be used in load bearing areas. Although our study was done on maxillary central incisor, still it proved to show the least value of compressive strength. Making it unsuitable for use in anterior teeth region also. Further research needs to be conducted to test these bulkfill flowable materials with different combinations of posts and teeth region so that they can be used wisely. However, more in vivo studies should be undertaken to check the clinical significance of these bulkfill materials when used in combination with Ribbond.

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ANNEXURE I

BABU BANARASI DAS COLLEGE OF DENTAL SCIENCES (FACULTY OF BBD UNIVERSITY), LUCKNOW

INSTITUTIONAL RESEARCH COMMITTEE APPROVAL

(Revised)

The project titled "**Comparative Evaluation of Fracture Resistance of Endodontically treated Teeth Restored with SDR Flow Plus, Beautifil, Tetric N Flow As Core Buildup Materials: An In Vitro Study**" submitted by **Dr Ananya Jain** Post graduate student from the **Department of Conservative Dentistry and Endodontics** as part of MDS Curriculum for the academic year 2019-2022 with the accompanying proforma was reviewed by the Institutional Research Committee present on **10th December, 2021** at BBDCODS.

The Committee has granted approval on the scientific content of the project. The proposal may now be reviewed by the Institutional Ethics Committee for granting ethical approval.

10/12/2021

Prof. Vandana A Pant
Co-Chairperson

10/12/21

Prof. B. Rajkumar
Chairperson

ANNEXURE II

Babu Banarasi Das University
Babu Banarasi Das College of Dental Sciences,
BBD City, Faizabad Road, Lucknow – 226028 (INDIA)

Dr. Lakshmi Bala
Professor and Head Biochemistry and
Member-Secretary, Institutional Ethics Committee

Communication of the Decision of the VIII[th] Institutional Ethics Sub-Committee

IEC Code: 13 (Revised) BBDCODS/12/2021

Title of the Project: Comparative Evaluation of Fracture Resistance of Endodontically treated Teeth Restored with SDR Flow Plus, Beautifil, Tetric N Flow As Core Buildup Materials: An In Vitro Study.

Principal Investigator: Dr. Ananya Jain **Department:** Conservative Dentistry & Endodontics

Name and Address of the Institution: BBD College of Dental Sciences Lucknow.

Type of Submission: Revised, MDS Project Protocol

Dear Dr. Ananya Jain,

The Institutional Ethics Sub-Committee meeting comprising following four members was held on 20[th] December, 2021.

1.	Dr. Lakshmi Bala Member Secretary	Prof. and Head, Department of Biochemistry, BBDCODS, Lucknow
2.	Dr. Amrit Tandan Member	Prof. & Head, Department of Prosthodontics and Crown & Bridge, BBDCODS, Lucknow
3.	Dr. Rana Pratap Maurya Member	Reader, Department of Orthodontics & Dentofacial Orthopaedics, BBDCODS, Lucknow
4.	Dr. Akanksha Bhatt Member	Reader, Department of Conservative Dentistry & Endodontics, BBDCODS, Lucknow

The committee reviewed and discussed your submitted documents of the current MDS Project Protocol in the meeting.
The comments were communicated to PI thereafter it was revised.

Decisions: The committee approved the above protocol from ethics point of view.

Forwarded by:

Lakshmi Bala 20/12/21

(Dr. Lakshmi Bala)
Member-Secretary
IEC

(Dr. B. Rajkumar)
Principal
BBDCODS

PRINCIPAL

ANNEXURE III

E-mail: cipetlko2@gmail.com
www.cipet.gov.in

CIPET : INSTITUTE OF PETROCHEMICALS TECHNOLOGY (IPT)
Dept. of Chemicals & Petrochemicals
Ministry of Chemicals & Fertilizers, Govt. of India
B-27, Amausi Industrial Area, Lucknow-226 008
Phone : 0522- [illegible], 7607194014
E-mail: cipetlko2@gmail.com
www.cipet.gov.in

Certificate No.CON – 040
Date: 13.01.2022

Issued to:

Dr. Ananya Jain,
MDS Student of Conservative Dentistry
& Endodontics Department
Babu Banarasi Das University,
BBD City, Faizabad Road,
Lucknow – 226 028 (U.P.) India

Page No 1 of 2

CERTIFICATE

PART-A

PARTICULARS OF SAMPLE SUBMITTED

Sample details	:	**Dental Sample** as stated by the party Your Ref. No. : BBDCODS/Gen-Corres/2022/5 Date : 05.01.2022
Size/Class	:	—
Quantity of samples	:	9 Sample (3 group)
Date of Manufacturing	:	—
Condition of receipt of sample	:	—
Sealed or not	:	Not sealed
Date of sample received	:	11.01.2022
Any other details	:	Payment received on 11.01.2022

Note:
(i) This Test Report Certificate is issued only for the samples submitted to CIPET.
(ii) The results stated above related only to the items tested.
(iii) The quality of the subsequent production lot has to ensured by the purchaser.
(iv) The test certificate shall not be reproduced in full except without the written approval of the laboratory.
(v) Statement of conformity of a specification or standard is provided by laboratory taking into account the level of risk associated/borderline cases with the decision rule employed.

PART-B

SUPPLEMENTRY INFORMATIONS

a)	Reference to sampling procedure wherever applicable	:	Supplied by the party
b)	Supporting documents for the measurements taken and Results derived like graphs, tables, sketches and/or Photographs as appropriate to test report, if any (to be attached).	:	Nil
c)	Deviation from the test methods as prescribed in Relevant work instruction, if any	:	Nil

Contd....2/-

मुख्यालय : गिण्डी, चेन्नई - ६०० ०३२

Head Office : Guindy, Chennai - 600 032

ANNEXURE IV

Group 1 Tetric N Flow Sample size

1	166.11
2	171.47
3	159.29
4	169.28
5	173/74
6	162.92
7	164.46
8	169.97
9	165.97
10	164.84

Group 2 Beautifill Sample size

1	95.34
2	78.34
3	88.45
4	97.43
5	81.73
6	91.58
7	92.72
8	75.95
9	85.92
10	87.48

Group 3 SDR Flow Plus Sample size

1	199.15
2	203.60
3	175.84
4	201.51
5	205.85
6	177.48
7	196.84
8	201.18
9	174.44
10	192.52

ANNEXURE V

Curiginal

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SA	**Comparative Evaluation of the Fracture Resistance of Various Fibro-Post -An Invitri Stusdy.docx** Document Comparative Evaluation of the Fracture Resistance of Various Fibro-Post -An Invitri Stusdy.docx (D82280759)	1
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