COMPARISON OF FRACTURE RESISTANCE OF IMMATURE TEETH FILLED WITH DIFFERENT ROOT CANAL FILLING MATERIALS– AN IN VITRO STUDY

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfilment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH IV

CONSERVATIVE DENTISTRY AND ENDODONTICS

APRIL 2020

CERTIFICATE

This is to certify that this dissertation titled **"COMPARISON OF FRACTURE RESISTANCE OF IMMATURE TEETH FILLED WITH DIFFERENT ROOT CANAL FILLING MATERIALS– AN IN VITRO STUDY"** is a bonafide record of work done by **Dr. R. JAYA SHREE ROJA** under my guidance and to my satisfaction during her Post Graduation study period, 2017 – 2020. This dissertation is submitted to **THE TAMILNADU Dr.M.G.R. MEDICAL UNIVERSITY**, in partial fulfilment for the award of the degree of Master of Dental Surgery in Conservative Dentistry and Endodontics, Branch IV. It has not been submitted (partial or full) for the award of any other degree or diploma.

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DECLARATION

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Duration of the Course	**2017 – 2020**
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I hereby declare that no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without getting prior permission from the Principal, Sri Ramakrishna Dental College and Hospital. In addition, I declare that no part of this work will be published either in print or in electronics without permission from the guide who has been actively involved in the dissertation. The author solely has rights for publishing this work with prior permission from principal, Sri Ramakrishna Dental College and Hospital, Coimbatore.

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CERTIFICATE -II

This is to certify that this dissertation titled **"COMPARISON OF FRACTURE RESISTANCE OF IMMATURE TEETH FILLED WITH DIFFERENT ROOT CANAL FILLING MATERIALS– AN IN VITRO STUDY"** of the candidate **Dr. R. Jaya Shree Roja** with registration number **241717301** for the award of **Master of Dental Surgery** in the branch of **Conservative Dentistry and Endodontics**. I personally verified the urkund.com website for the purpose of plagiarism check. I found that the uploaded thesis file contains from introduction to conclusion pages and result shows **1** percentage of plagiarism in the dissertation.

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ACKNOWLEDGEMENT

This thesis is the result of hard work with immense support from many people and it is with immense pleasure that I express my heartfelt gratitude to all of them.

I owe an immense debt of gratitude to my guide **Dr. V. Prabhakar, MDS, Head of Department**, Department of Conservative Dentistry and Endodontics, Sri Ramakrishna Dental College and Hospital, for his unwavering guidance, immeasurable encouragement and constant support during my post graduate tenure. I am also grateful to him for his innovative ideas, constructive suggestions, valuable criticism and constant encouragement.

My sincere thanks to **Dr. J. Dinakar, M.D.S, Principal**., Sri Ramakrishna Dental College and Hospital, who has helped me with his advice and immense support throughout my postgraduate curriculum.

I take this opportunity to express my sincere gratitude to **Dr. Minu Koshy, MDS, Professor., Dr. Subha Anirudhan, MDS, Professor., Dr.Ambalavanan, MDS, Reader., Dr. Gayathri V, MDS, Senior Lecturer., Dr. Remya Verghese, MDS, Senior Lecturer., Dr. S. Sakthivel, MDS, Senior Lecturer., Dr. Hari Bhaskar, MDS, Senior Lecturer., Dr. Poojitha Vishwanath, MDS, Senior Lecturer., Dr. Anita, MDS, Senior Lecturer** who supported me at every juncture throughout my postgraduate curriculum.

I sincerely acknowledge **Dr.Krupa.M.D.S., Department of Public health dentistry ,** JKK Nataraja Dental College, Tiruchengode for her guidance in statistical analysis of the study.

I also thank my colleagues **Dr. P. Revathi** and **Dr. S. Mohamed Ashif Anifa,** for their encouragement and unwavering support and undeniable belief in my abilities which gave me inspiration throughout this journey. I would like to sincerely thank my seniors and juniors for helping me to complete my dissertation and giving me their unwavering support during the course.

I express my gratitude to my parents **Mr. V. Ramasubbu** and **Mrs. R. Sankari** and to my sisters. No amount of words can justify or express their love, support, sacrifice, encouragement and inspiration they have given me and made me the person of what I am today.

For all the people I have acknowledged here, above everyone I bow my head to the **Almighty**.

Dr. R. Jaya Shree Roja

CONTENTS

ABSTRACT

Introduction: To compare the fracture resistance of simulated human permanent immature teeth restored with different root canal filling materials as an apical plug after 3 months of aging.

Methods: Eighty single rooted extracted mandibular premolars were selected. The roots of teeth were standardized to a length of 10 mm as measured from the apex to the facial cementoenamel junction (CEJ) by cutting the root tip to simulate incomplete root formation. To achieve a simulation of teeth with immature apices, Peeso Reamers between #1 and #6 were introduced into the root canal until #6 pass freely out of the apex. Further 703 carbide bur was used to obtain the remaining dentin thickness around 1 to 1.5 mm. The teeth were randomly divided into 4groups (n = 20 for each group. In Group A, An immature tooth model were left unfilled without any reinforcement material (Control group). In Group B, the root canals were filled with 4mm apical plug of Biodentine and then backfilled with gutta-percha/AH Plus obturation. In Group C, 4mm apical plug of DiaRoot Bio Aggregate and then backfilled with gutta-percha/AH Plus obturation. In Group D, teeth were filled with 4mm apical plug of MTA-Angelus was placed in the root canal and then backfilled with gutta-percha/AH plus obturation. All root specimens were stored for 3 months at 100% humidity to allow the complete setting of the sealers. Each specimen was then subjected to fracture testing by using a universal testing machine at a crosshead speed of 1.0 mm/min until the root fractured. The force required to fracture each specimen was recorded, and the data were analysed statistically.

Results: The Biodentine group (Group B) had the highest fracture resistance that differed significantly ($p < 0.05$) from the other groups. There was statistically significant difference between group C (Bio Aggregate) and group D (MTA-Angelus) ($P< 0.05$). Group A (control group) had the lowest fracture resistance that differed significantly ($p < 0.05$) from the other groups.

Conclusion:

Within the limitations of this study, data suggests that the use of 4mm apical plug of Biodentine increased the fracture resistance of immature teeth compared with MTA angelus, Bioaggregate.

Traumatic dental injuries are frequent in children aged 8– 12 years, and the maxillary incisors are the most commonly affected teeth. A traumatic impact on the immature anterior teeth frequently results in arrested root development due to the loss of pulp vitality. The endodontic treatment of these teeth with necrotic pulps poses a challenge for the practitioner because of the widely open apices and the thin dentinal walls which predispose teeth to fracturing[1, 2]. Root fractures commonly occur in the cervical third and have been shown to have a rate of about 28–77%, depending on the stage of root development, with the highest percentage of fractures occurring in teeth with the least developed root. Numerous materials have been recommended for the apexification of immature teeth up to date. Calcium hydroxide (CH) has been used for the induction of an apical barrier in immature teeth due to the high pH and antimicrobial activity for years[3, 4]. However, CH has some disadvantages; the CH treatment may extend up to 1 year and this may decrease the fracture.

Single visit apexification using Mineral Trioxide Aggregate has recently been advocated to overcome these difficulties inherent in long-term Calcium hydroxide treatment, and it has resulted in favorable clinical outcomes[5, 6]. Immediate apical barrier formation using MTA offers several advantages over conventional apexification, such as reduced risk of subsequent cervical root fracture and increased patient compliance The search for bioceramic materials exhibiting properties similar to MTA but with improved handling characteristics and shorter setting times has led to the development of newer products which have been referred to as calcium silicate based cements. BioAggregate (BA) (Innovative BioCeramix Inc.,Vancouver,BC,Canada), a tricalciumsilicate-based and aluminum-free ceramic biomaterial, has been developed for use in retrograde root filling, repair of root perforation, apexification, vitalpulptherapy, and pulpcapping[7,8]. Although all calcium silicate-based materials induce clinically perceptible color changes, Bioaggregate is advantageous since they exhibit less discoloration than MTA[9, 10]. Ongoing efforts have been directed towards searching for materials with improved biological and mechanical properties. Furthermore, there has been limited information on the strengthening capacity of novel root canal filling materials. In this regard, the aim of this in vitro study was to assess the long-term fracture strength of simulated human immature permanent teeth filled with Biodentine, Bio Aggregate and Mineral trioxide Aggregate using universal testing machine.

TABLE 1

MATERIAL	**COMPOSITION**	**MANUFACTURER**
Bio Dentine	Tricalcium silicate, dicalcium silicate, Calcium carbonate and oxide filler, Iron oxide shade, and zirconium oxide	Septodont, USA
BioAggregate	Tri calcium silicate, Di calcium silicate, Tantalum pentoxide, Calcium phosphate mono basic , Amorphous silicon oxide	Dia Dent Group International, Canada
MTA-Angelus	Tricalcium silicate, Di calcium silicate, Tricalcium aluminate, Tetra calcium alumina ferrite, Bismuth oxide	Angelus, Londrina, PR, Brazil

The purpose of this study was

- To compare the fracture resistance of simulated permanent immature teeth restored with Biodentine, Bio Aggregate and Mineral Trioxide Aggregate as an apical plug after 3 months of aging under Universal Testing Machine

Goldberg F et al (2002)[11] compared the fracture resistance of fifty six maxillary human central incisors. The length of the crown was standardized to 13 mm.Root canals were enlarged to simulate the immature teeth. All teeth were subjected to fracture testing using an Instron testing machine The difference between groups was statistically significant and they concluded that the canal walls which was filled with resin modified GIC and post had higher fracture resistance than control groups

Lawley GR et al (2004)[12] evaluated the various placement techniques of mineral trioxide aggregate (MTA) and apical plug thickness needed for fracture resistance . They concluded that Mineral trioxide aggregate(4mm) with composite resin had higher fracture resistance than Mineral trioxide aggregate with Gutta Percha.

Hatibovic-Kofman S, Raimundo L (2006)[13]tested the long term fracture resistance of calcium hydroxide and MTA. They concluded that the fracture resistance were not significantly different from the non-treated, calcium hydroxide treated and MTA treated teeth at two-week or two-month. The teeth filled with MTA had the highest fracture resistance at one year.

Andreasen JO et al (2006)[14] tested the fracture resistance of immature teeth using a root filling of calcium hydroxide (CH) and mineral trioxide aggregate material (MTA). They concluded that 30 day placement of calcium hydroxide did not affect the fracture resistance of teeth significantly.

Stuart CH et al (2006)[15] compared the strengthening ability and reinforcing effect of composite resin , gutta perch and resilon in root canal treated roots of immature teeth. Fracture resistance was tested using universal testing machine and peak newtons were loaded. They concluded reinforcement is not necessary for wall with diameter of diameter of 1.5 mm or less.

Wilkinson KL (2007)[16] evaluated the fracture resistance of simulated immature teeth filled with flowable composite resin, hybrid composite resin, gutta percha and resilon. Each root was fracture tested horizontally using Instron universal testing machine . They concluded that the hybrid composite resin significantly had higher fracture resistance more fracture resistant than positive controls.

Moosavi H et al (2008)[17] compared the fracture resistance immature teeth reinforced using three different restorative methods. They concluded that reforpin can be used an alternative for composite. They concluded that Reforpin or fiber post had higher fracture resistance than resin cement.

Teixeira FB et al (2004)[18] evaluated the resistance of simulated immature teeth to fracture restored with gutta percha and resin composite. They concluded canals restored with the composite material reinforced canal wall compared to gutta percha. Hence the composite material can be used as reinforcement material in simulated immature teeth as the results of this study indicate that increases the fracture resistance of teeth.

Bose R et al (2009)[19] retrospectively evaluated radiologic outcomes in simulated immature teeth with necrotic system treated with regenerative endodontic procedures. The results showed triple antibiotic paste produced significant difference when compared to formocresol or calcium hydroxide groups when used as intracanal medicament.

Hemalatha H et al (2009)[20] compared the reinforcement ability of gutta percha, ribbond and resilon. They concluded that ribbond had higher fracture resistance and it had no statistically significant difference when compared to other groups.

Nagas E et al (2010)[21] compared the root reinforcement ability of RMGIC, resilon, gutta percha and Fiber reinforced composite. They concluded that the use of RMGIC significantly improved the fracture resistance and MTA doesnot have any reinforcing effect.

Al-Kahtani AM et al (2010)[22] investigated the fracture resistance of root canal treated teeth restored with a resin based obturation material using different chelating agents. They concluded that obturating the root canals with RealSeal increased fracture resistance. Teeth placed with MTAD had high fracture resistance values when compared to teeth treated with 17% EDTA. However it was not statistically significant and obturating the root canals with RealSeal with increased bonding to roots will increase resistance

Schmoldt SJ et al (2011)[23] evaluated the resistance to fracture of simulated immature teeth restored with MTA, Gutta pecha, Fiber post. All teeth were subjected to thermocycled. Teeth were subjected to fracture testing horizontally using an Instron Universal Testing Machine. They concluded that the fiber reinforced composite with a fiber post was the material that significantly strengthened the simulated immature teeth.

Tuna EB et al (2011)[24] assessed fracture resistance of human immature teeth restored with bioaggregate and MTA after 24 months. The specimens were fracture tested under universal testing machine. They concluded that the use of bioaggregate significantly improved the fracture resistance of teeth

Milani AS et al (2012)[25] investigated the reinforcing ability of mineral trioxide aggregate and Calcium enriched mixture cement on simulated immature teeth. The teeth were subjected fracture strength under universal testing machine. They concluded that after 6 months, mineral trioxide aggregate and Calcium enriched mixture cement exhibited distinct reinforcing effect on simulated immature teeth.

Güneş B et al (2012)[26] **treated** three maxillary incisors with open apices and periapical lesions with MTA. It was restored with 3mm of apical plug of MTA and backfilled with compositer resin. At a 1 year and 18 months follow up, radiological and clinical successful healing of the incisor teeth was seen. They concluded that MTA seems as an effective material when used as apical plug for the treatment of non-vital immature permanent teeth with open apex. .

Seto B et al (2013)[27] evaluated the depth and type of restoration that will be effective in simulated immature permanent maxillary anterior teeth in terms mode of failure and resistance to fracture. MTA apexification was done and all the teeth were mountedsimulated to Cveks stage 3 root development. They concluded that use of quartz fiber post increased the resistance of the roots in immature teeth significantly.

Dikbas I et al (2014)[28] assessed the fracture resistance of immature simulated teeth with three different post systems and MTA. They concluded that there was no significant difference between post systems used and all the systems reinforced the root

Nagy MM et al(2014)[29] investigated the regenerative ability of permanent immature teeth with necrotic pulp after the treatment protocols including placement of mineral trioxide aggregate (MTA) apical plug, and using the regenerative endodontic protocol (blood clot scaffold) and using the regenerative endodontic protocol with a blood clot and an injectable scaffold which was impregnated with basic fibroblast growth factor. They concluded that regenerative procedures permitted the continued development of roots in teeth with pulp necrosis. They also concluded that the use of and basic fibroblast growth factor and artificial hydrogel scaffold was not necessary for repair.

Topçuoğlu HS et al (2015)[30] assessed the fracture resistance of teeth apically restored with biodentine with different obturation combinations. Specimens were subjected to fracture testing. They concluded that the material which biodentine plug with fiberpost had the highest fracture resistance among other groups.

Bolhari B et al (2015)[31] evaluated the fracture resistance of permanent simulated immature teeth, back filled with Gutta-percha or Resilon and which was reinforced by either fiber post or composite resin. Specimens were subjected to fracture testing with Instron universal Testing Machine. They concluded that the use of fiber posts in simulated immature permanent teeth provided the most favorable outcome.

Evren OK et al (2016)[32] assessed the fracture resistance of permanent simulated immature teeth filled with an placement of 4mm apical plug of mineral trioxide aggregate, Biodentine, and calcium-enriched mixture. Teeth were stored at 37°and tested under universal testing machine. They concluded that the Biodentine, mineral trioxide aggregate and Calcium enriched mixture with fiber post increased the fracture resistance and there were no statistically significant differences found among Mineral trioxide aggregate, Calcium enriched mixture, and Biodentine.

Karapinar-Kazandag M et al (2016)[33] assessed the fracture resistance of mineral trioxide aggregate and two different composite material. Specimens were mounted in universal testing machine and subjected to fracture testing. They concluded MTA And composite materials increased the fracture resistance of the teeth compared with intact teeth.

Guven Y et al (2016)[34] evaluated the fracture resistance of simulated human immature teeth apically filled with ERRM, MTA AND Bio aggregate. They suggested that bioaggregate had higher fracture resistance and is the most promising material.

Elnaghy AM, Elsaka SE (2016)[35] evaluated the reinforcing ability of simulated immature teeth restored with Biodentine and mineral trioxide aggregate Each model was subjected to fracture resistance testing using a instron universal testing machine. They concluded that after 12 months there was no statistically difference between white MTA and Biodentine regarding the fracture resistance of the teeth.

Lin J-C et al (2016)[36] compared the efficacy of calcium hydroxide and MTA for apexification of immature permanent teeth. They concluded that both the mta and calcium hydroxide materials provided similar success rates but the higher patient compliance and shorter treatment time with MTA may provide higher overall success rates

Bayram E et al (2016)[37] evaluated the fracture resistance of teeth restored with biodentine , MTA and Bioaggregate Instron universal testing machine was used to determine the load to fracture the the teeth by placing the tip 3millimeters incisal to the cemento enamel junction. They concluded that the three materials can be used as effective reinforcement agents for immature permanent teeth.

Girish K et al (2017)[38] evaluated the resistance to fracture of immature permanent simulated teeth. Teeth were filled with 5mm of biodentine and compared with of roots filled with conventional apexification procedure. All the teeth were subjected to fracture testing using the universal testing machine. They concluded that the teeth restored with bioactive materials had highest fracture resistance than conventional groups.

Çiçek E, Yılmaz N, Koçak MM et al (2017)[39] investigated the fracture resistance of teeth filled with varying thickness of MTA. MTA was filled for 3mm and 6mm and back filled with gutta percha. They concluded that teeth filled with 3mm had higher fracture resistance.

Aksel H et al (2017)[40] investigated the fracture resistance of mineral trioxide aggregate in immature permanent roots. They concluded that MTA increases resistance of immature permanent teeth to Vertical root fracture and mixing Mineral trioxide aggregate with Chlorhexidine or Polyethylene glycol as the vehicle do not alter Vertical root fracture resistance of immature permanent teeth.

Zhabuawala M et al (2017)[41] investigated the resistance to fracture of simulated immature permanent teeth apically restored with biodentine with composite resin and only with biodentin. They concluded that biodentine group had least fracture resistance after 3 months and is not recommended for long term.

Altaii M et al (2017)[42] evaluated restrospectively the outcome of immature teeth undergone with regenerative procedure. They concluded that there were more hard tissue development in apical portionand teeth with regenerative procedures had positive outcomes.

Jamshidi D, Homayouni H, Moradi Majd N et al (2018)[43] compared the fracture resistance of simulated immature permanent teeth restored with mineral trioxide aggregate reinforced with post ,treated with regenerative procedures . Fracture resistance was tested under instron universal testing machine. They concluded that no modalities which was tested had significant increase in fracture resistance teeth

Linsuwanont P et al (2018)[44] compared the fracture resistance of simulated human immature teeth filled with MTA, Fiber post and gutta percha. All teeth were thermocycled and tested under an Instron universal testing machine. They concluded that after all the groups had significant increase in fracture resistance than control groups.

Aktemur Türker S et al (2018)[45] investigated with internal resorption which had perforations. It was repaired with silicate-based cements and backfilled with different materials. Specimens were tested under universal testing machine. The highest Fracture resistance was observed in group completely restored with Biodentine and the lowest fracture resistance was seen in group restored with MTA Plus and gutta-percha/sealer combination.

Belli S et al (2018)[46] investigated the effect of various materials in formation of stress pattern . calcium hydroxide increased the stress of root compared with temporary material.They concluded that the Calcium hydroxide is not a ideal material as a temporary dressing .

Awawdeh L et al (2018)[47] conducted randomized controlled study of vital permanent teeth with deep caries. Clinical assessment were done. Teeth were restored with biodentine and mineral trioxide material as pulp capping material. They concluded that they had successful outcomes.

Lee L-W et al (2019)[48] evaluated the outcome of immature teeth with open apex treated with MTA using fiber mesh. It was placed to prevent extrusion of MTA materials into the periapical tissues of open-apex teeth. They concluded that the this combination is an best technique for treatment of immature opex apex teeth which are necrotic.

Sarraf P et al (2019)[49] compared the fracture resistance of immature teeth restored with ProRoot MTA, Calcium enriched mixture Cement, and Biodentine as root filling materials. In all groups 5-mm apical plug was placed with a temporary restorative material. They concluded that there was no significant difference was calcium enriched mixture Cement, gutta-percha and AH26.

Ali MRW et al (2019)[50] compared the resistance to fracture of simulated immature permanent teeth after treating with regenerative endodontic procedure using cervical plug of Mineral-Trioxide-Aggregate, Biodentine and TotalFill. Teeth were treated with a Regenerative endodontic protocol consisting of usage of sodium hypochlorite and ethylene diamine tetra acetic acid irrigation, 14 day placement of intracanal medication with triple-antibiotic paste for followed by a Tri calcium silicate cements cervical seal and composite restoration. Teeth were then subjected to an increasing compressive force using Universal Testing Machine. They concluded that Tricalcium silicate cements placed at the cervical area of did not increase fracture resistance.

MATERIALS:

SAMPLES:

- Freshly extracted Maxillary central incisors were stored in physiological normal saline.

IRRIGANTS:

- Sodium Hypochlorite 3% **(Novo Dental Products PVT LTD, Mumbai)**
- Ethylene diamine tetra acetic acid - EDTA 17% **(DenoR , DenSMEAR,**

Red Gold Mines Bangalore)

- Saline **(0.9% NS- 5OO ml, Claris Otsuka, Ahamedabad)**

OBTURATION:

- Bio Aggregate **(DiaDent, Canada).**
- MTA- Angelus **(Angelus, Londrina, Brazil)**
- AH Plus. **(Dentsply,Switzerland)**
- Biodentine **(Septodont, France)**
- ProTaper Gutta Percha cones – Size F3 **(Dentsply Maillefer; Ballaigues, Switzerland)**
- **Cavit (3M ESPE, Seefeld,Germany)**

ARMAMENTARIUM:

- Diamond Saw
- Carbide burs **(Mani, Japan)**
- Diamond Round Burs **(Mani, Japan)**
- Size 10, 15 – K Files **(Mani, Japan)**

- Peeso reamers size 1-6 (**Mani, Japan)**
- 5 ml Disposable syringe **(Dispovan, Hindusthan Syringes and Medical Device Faridabad, India)**
- X Smart EndoMotor **(DENTSPLY Maillefer; Ballaigues, Switzerland)**
- ProTaper paper points **(Dentsply Maillefer; Ballaigues Switzerland)**
- Polyether impression material **(3M ESPE, USA)**
- Lentulo Spirals **(Dentsply Maillefer; Ballaigues, Switzerland)**
- Contra-angled Micromotor Hand Piece **(NSK, Japan)**
- Tweezers **(GDC)**
- DPI Cold cure **(India)**
- Mixing pad, Spatula
- Hand Pluggers **(Dispodent, Chennai, India)**
- GP Condenser (**Dispodent, Chennai, India)**

METHODS:

A total of 80 freshly extracted human maxillary central incisors that were extracted due to periodontal reasons were used in the current study (Fig: 1). The selection of teeth was based on confirmation of the preoperative radiographs of the absence of previous root canal treatment, cracks, resorptions, or calcifications. Moreover, dimensions of each tooth at the cemento enamel junction (CEJ) were measured using digital calipers (Fig: 2). The roots of teeth were standardized to a length of 10 mm by cutting the root tip to simulate incomplete root formation when measured from the apex to the cementoenamel junction (CEJ). Endodontic access cavities were made using round bur in a high-speed handpiece. Peeso Reamers between #1 and #6 were introduced into the root canal until #6 pass freely out of the apex to simulate immature open apex. After instrumenting with Peeso reamers, the radicular dentin thickness was 2.5 mm. Further 703 carbide bur was used to obtain the remaining dentin thickness around 1 to 1.5 mm. The samples were then subjected to CBCT analysis to confirm the dentin thickness. Irrigation was done using 3 ml of 3% sodium hypochlorite and finally with 5 ml of 17% Ethylene diamine tetra acetic acid. Canals were restored with materials according to manufacturer’s instructions.

The teeth assigned to four groups randomly (n=20) given as follows.

Group A: Control group

Group B: Biodentine (Septodont, Saint Maur des Fosses, France)

Group C: DiaRoot BA (BA (DiaDent Group International, Canada).

Group D: MTA-Angelus (MTA-A) (Angelus Solucoes Odontol´ogicas, Londrina, PR, Brazil).

In Group A- Control group, the immature tooth models were left unfilled without any reinforcement material. In Group B- Biodentine group (Fig: 3) the liquid from container was olaced in capsule with powder and mixed for 30 seconds at 4000–4200 rpm. Condensation was done using pluggers (Fig: 4). In Group C- Bio Aggregate (Fig 5), Bioaggregate powder was mixed according to manufacturers instructions(1 g powder with 0.38 ml of liquid). Teeth were restored using lentulospiral and condensed with pluggers.(Fig 6). In Group D- MTA Angelus (Fig: 8), the placement of white MTA-A was using a lentulo spiral and then condensation was done using pluggers (Fig: 9). The coronal parts of teeth were covered with a moist cotton for 24 hours before permanent restoration is placed. The specimens were stored for three months until fracture resistance was tested in 100% humidity at 37∘C (Fig: 10)

FRACTURE TESTING:

The surfaces of root were covered with a polyether impression material to mimic the periodontal membrane. The roots were mounted in self-curing resin (Fig: 11). Each specimen was placed in a universal testing machine (Instron, Japan). The spade, which was used to apply the force to the specimen, was placed on the facial surface at 90 ° to the long axis of the tooth in a buccal/lingual direction at a point 3 mm above the cementoenamel junction to stimulate a traumatic blow on the middle third of the dental crowns . The samples were loaded at a speed of 1 mm /min untill the fracture occured. The peak load was recorded in newtons (Fig 12)

FIG 1: SIMULATED IMMATURE PERMANENT MAXILLARY CENTRAL INCISORS

FIG 2: MATERIALS USED IN THIS STUDY

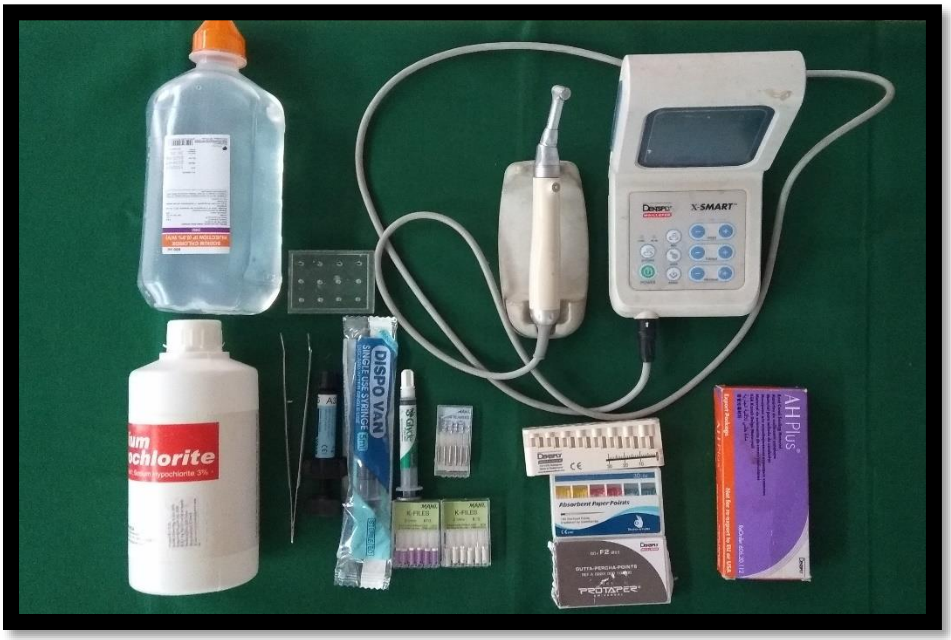


FIG 3 : BIODENTINE

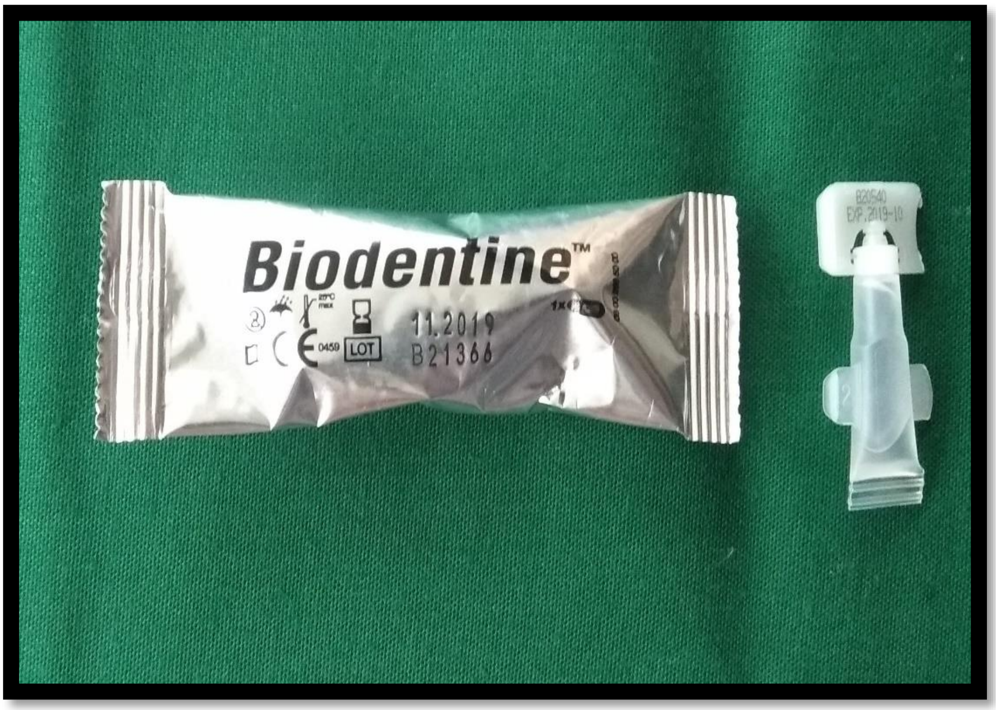


FIG 4:BIODENTINE CAPSULE AND POWDER

FIG 5: SIMULATED IMMATURE TEETH APICALLY RESTORED WITH BIODENTINE

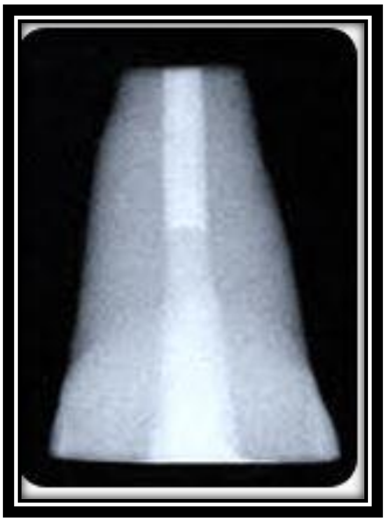


FIG 6: BIOAGGREGATE

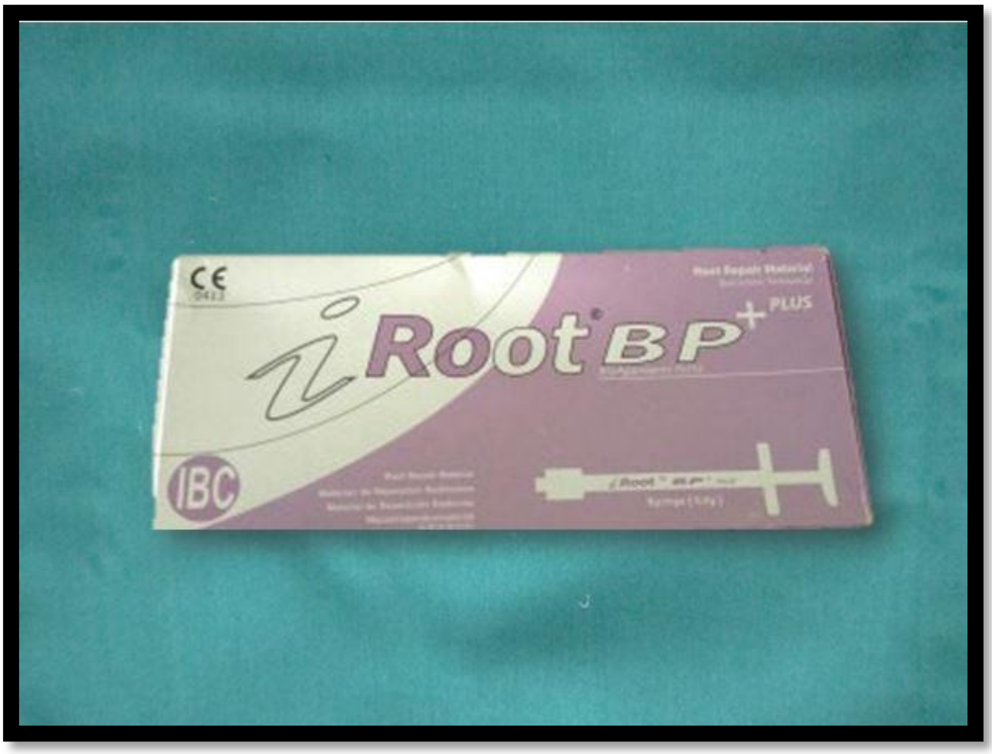


FIG 7: SIMULATED IMMATURE TEETH APICALLY RESTORED WITH BIOAGGREGATE

FIG 8: MTA ANGELUS

FIG 9: SIMULATED IMMATURE TEETH APICALLY RESTORED WITH MTA ANGELUS

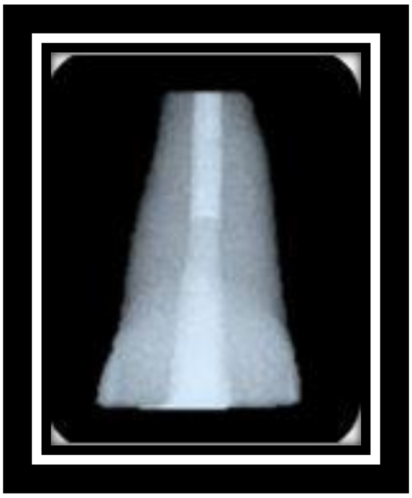


FIG 10: INCUBATOR

FIG 11: TEETH MOUNTED IN ACRYLIC MODEL FOR FRACTURE TESTING

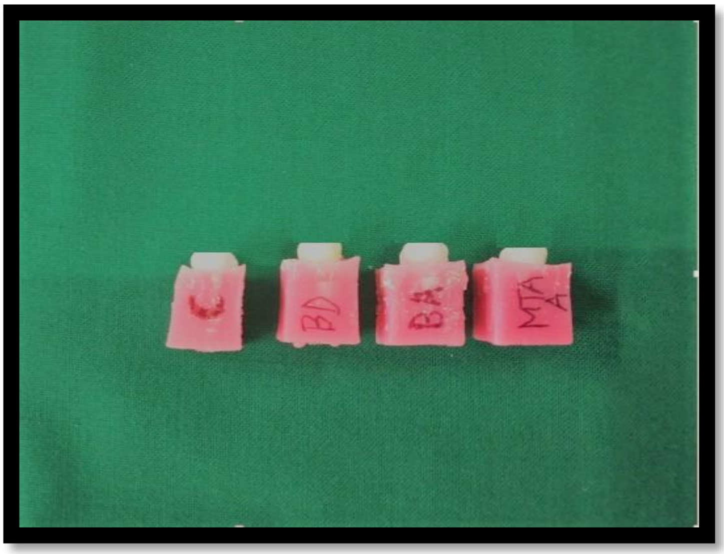


FIG 12 : TEETH SAMPLE MOUNTED ON UNIVERSAL TESTING MACHINE FOR FRACTURE TESTING

STATISTICAL ANALYSIS:

SPSS 22.0 software (SPSS Inc, Chicago, IL) was used for statistical analysis. The mean values and their respective standard deviations of the force required to fracture the roots are presented in Table2. The strongest mean force required to fracture the roots was seen in the Group B- Biodentine group whereas the weakest force required was seen in the Group A- Control group(Fig 13)

The mean values and their respective standard deviations of the force required to fracture the roots are presented in Table2. The strongest mean force required to fracture the roots was seen in the Group B (Biodentine group) whereas the weakest force required was seen in the Group A (Control group) (Fig 13)

In the present study, the mean fracture resistance using Universal testing machine was found to be highest in the Group B- Biodentine group (578.32 ± 15.46) followed by Group C- Bio Aggregate (540.81± 18.55) and Group D- MTA Angelus(518.21±25.71). The control group (417.43±13.37) showed lower fracture resistance (Fig 14)

Significant variations ($P < 0.05$) between the groups were observed in ANOVA test (Table 3). Post hoc Tukey analysis showed that there were significant differences between the experimental groups and control groups. (Table 4)

To summarise,

- Biodentine group had significantly high fracture resistance compared to other groups
- Bioaggregate group showed higher fracture resistance than MTA Angelus and control group.
- Control group showed the least fracture resistance and had statistically significant lower fracture resistance compared to other groups

TABLE 2: MEAN, STANDARD DEVIATION, MINIMUM AND MAXIMUM VALUES OF EACH GROUP

Groups	N	Mean Force (N)	Std. deviation	Minimum	Maximum
CONTROL	20	417.43	13.37	395.28	444.93
BIODENTINE	20	578.32	15.46	534.77	599.23
BIOAGGREGATE	20	540.81	18.55	490.12	576.34
MTA ANGELUS	20	518.21	25.71	485.74	569.86
Total	80	513.69	62.75	395.28	599.23

TABLE 3:

Groups	N	Mean Force (N)	Df	F	p value
CONTROL	20	417.43	3	266.107	0.000
BIODENTINE	20	578.32			
BIOAGGREGATE	20	540.81			
MTA ANGELUS	20	518.21			

$p < 0.005$ – statistically significant

Analysis of variance was used to analyse the difference between various test groups. It was seen that there was statistically significant difference within the groups (p = 0.000). Hence the further analysis was done using Tukeys Post Hoc test to analyse the difference between the groups.

TABLE 4: MULTIPLE COMPARISONS

GROUPS	COMPARISON	MEAN DIFFERENCE	p value
CONTROL	BIODENTINE	-160.893838888531600	.000
	BIOAGGREGATE	-123.377971999789110	.000
	MTA ANGELUS	-100.782873534607000	.000
BIODENTINE	BIOAGGREGATE	37.515866888742494	.000
	MTA ANGELUS	60.110965353924600	.000
BIOAGGREGATE	MTA ANGELUS	22.595098465182105	.002

Tukey’s post hoc analyses show that there is statistically significant difference between the control and experimental and also between the experimental groups.

FIG 13: DISTRIBUTION OF MEAN VALUES OF DIFFERENT GROUPS

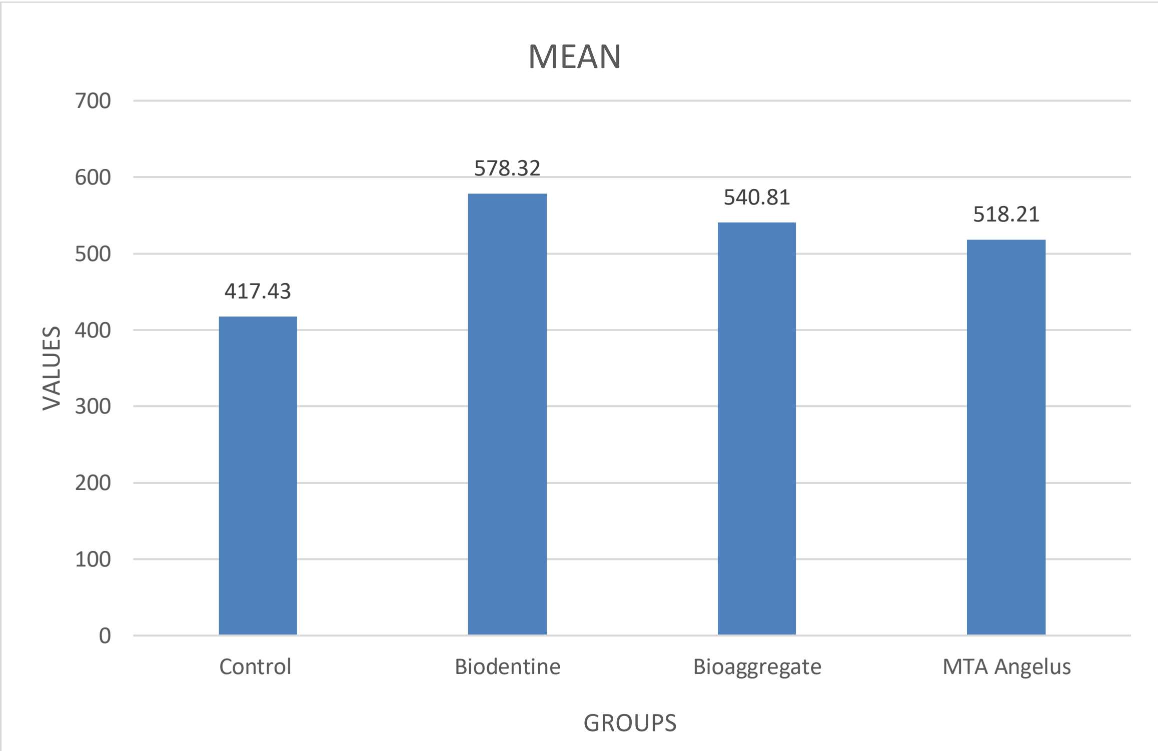
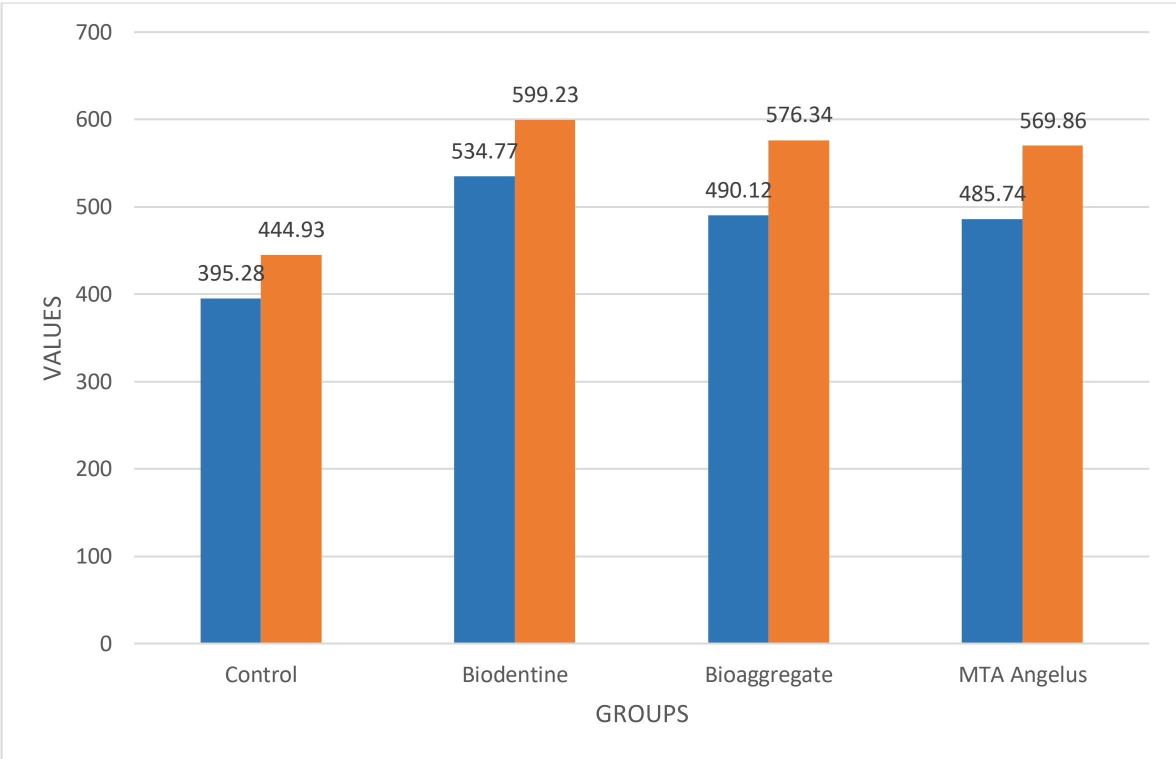


FIG 14: MINIMUM AND MAXIMUM VALUES IN EACH GROUPS



DISCUSSION:

Immature teeth present a problem during routine root canal obturation due to their anatomy and root canal configuration as the roots are short and thin. Their fracture resistance depends on the remaining dentinal wall thickness and root length. Hence, Reinforcement of immature teeth is necessary to improve the fracture resistance of the teeth. Materials used for reinforcement should be applied easily in clinical practice, bond successfully to dentin and should serve as a good barrier against microleakage[51]. The site of maxillary central incisor teeth explains its high susceptibility to trauma and external impacts; thus, in the current study, they were selected for testing

In most of the studies, found in the literature, to simulate immature teeth, the canals were instrumented with Peeso reamers (1–6) until a size 6 Peeso reamer that can be passed 1 mm beyond the apex to simulate open apex but this would only result in dentin thickness of 2–2.5 mm. Studies have revealed that the reinforcement of a canal with a diameter <1.5 mm is not necessary. Hence wall thickness of 2.63 mm is insufficient to decrease the fracture resistance of teeth[52]. So in the present study preparation of the canal was further enlarged with 702 carbide burs to simulate Cvek's stage 3 root development. The root-to-canal ratio in a mesiodistal dimension at the CEJ is nearly 1:1 at Cvek's stage 3 root. In the present study, after the simulation of all the samples, cone-beam computed tomography was used to find out the accurate thickness of the remaining radicular dentin.

For testing fracture resistance, teeth were embedded in acrylic resin, and periodontal membrane simulation was performed using a polyether impression material to simulate the clinical situation[53]. Furthermore, a loading angle of 135° was selected to mimic the average angle of contact between maxillary and mandibular incisors in a class 1 occlusion[54]

Various materials including composite resins, resin-reinforced glass ionomers, resin-based root canal fillings (Resilon), different post systems, and different root-end filling materials, such as MTA and BA have been used to reinforce the immature permanent teeth.

A survey of recent literature indicated that there was no investigation on the comparison of Biodentine, MTA and Bioaggregate as apical plug on the root fracture resistance of the immature teeth done after 3 months of aging. In the present study, we used MTA, Biodentine, and Bioaggregate as apical plug and gutta percha and composite resin for the restoration of immature teeth.

Mineral trioxide aggregate was assessed in the present study as an artificial apical barrier due to its adaptation, low microleakage, pH 12.5 when set, adequate radiopacity, amenability to hard tissue deposition over its surface, and favorable clinical outcomes[55]. In addition, MTA may indirectly affect the inhibition of dentin metalloproteinase, possibly preventing degradation of the dentin collagen matrix[56] and it may bond with root dentin that is initially mechanical and later becomes chemical[57]. The selection of the use of 4 mm MTA apical barrier in the current study was due to the best sealing ability compared with thinner applications in agreement with Valois and Costa[58]. However, MTA has some disadvantages. Therefore, Biodentine and Bioaggregate was selected as an alternative apical barrier in the present study.

Biodentine cement is of the same category as MTA. It is biocompatible, capable of inducing the apposition of reactionary dentin by stimulating odontoblast activity and reparative dentin by induction of cell differentiation. Its consistency is better suited to clinical use than that of MTA, its presentation ensures a better handling and safety than that of MTA, and faster setting and lower risk of bacterial contamination than with MTA[59,60].

Bio Aggregate is composed of fine nanoparticle-size, aluminium free powder that is mixed with deionized water to form a bioceramic paste[61]. Bioaggregate contains hydroxyapatite, which has been proposed as an addition to root-end filling materials inorder to enhance their ability to form a biochemical bond to the bone[62].

In the present study, Biodentine (Group B) had the higher fracture resistance when compared to Bio Aggregate (Group C) and MTA Angelus (Group C). Biodentine includes additives to enhance the material properties. These include calcium carbonate which is present in the powder, calcium chloride and water soluble polymer in the liquid. The calcium carbonate is a source of free calcium ions that are present in solution as soon as the powder is mixed to the liquid. Their presence results in a higher heat flux earlier in the reaction thus enhancing the reaction rate. The calcium chloride reduces the setting time of the Biodentine considerably when compared to other similar material types[63,64]. The water soluble polymer enables the reduction of the water to cement ratio thus enhancing the Biodentine's physical properties. In fact the compressive strength and micro-hardness of Biodentine are much higher than those reported for other similar material types[65]. The specific material chemistry, the fine particle sizes, the low water to cement ratio and the presence of calcium carbonate all contribute to optimal materials properties aimed for clinical performance. The material also exhibits low porosity when compared to similar material types which is beneficial clinically. This could be attributed to their higher fracture resistance. These results are in aggrement with the studies done by Guenesar et al[66]

The high fracture resistance of Bio Aggregate in comparison with MTA Angelus may be attributed to the absence of calcium hydroxide in the aged cement considering the negative long-term effects of calcium hydroxide on the fracture susceptibility of the root. Camilleri et al. investigated the effects of additives on the hydration mechanism of BA by characterization of the unhydrated and hydrated forms, using a combination of techniques and comparing these properties to MTA-Angelus[67]. Tricalcium silicate in BA results in calciumsilicate hydrate and calciumhydroxide following setting reactions. The former was deposited around the cement grains, while the latter reacted with the additive in Bio Aggregate, silicon dioxide, to form additional calcium silicate hydrate. This resulted in very low levels of calcium hydroxide in the aged cement thus enhancing the mechanical properties of the cement. MTA-Angelus reacted in a similar fashion; however, since it contained no additives, the calcium hydroxide was still present in the aged cement. Our results are in consistent with study done by Tuna et al[68].

Biodentine filled immature teeth have higher fracture resistance than other groups at 3 months. In addition, the teeth filled with MTA-Angelus demonstrated significantly lower strength to fracture in comparison with other groups. Considering the risk of fracture in the long term, it seems that Biodentine could be a promising material. However, Further research is necessary to validate the findings obtained in the present study.

This in vitro study aimed to compare the fracture resistance of simulated permanent immature teeth restored with Biodentine, Mineral Trioxide Aggregate and Bio Aggregate as an apical plug after 3 months of aging under Universal Testing Machine

A total of 80 freshly extracted human maxillary central incisors that were extracted due to periodontal reasons were used in the current study. The selection of teeth was based on confirmation of the preoperative radiographs of the absence of previous root canal treatment, cracks, resorptions, or calcifications. Moreover, dimensions of each tooth at the cemento enamel junction (CEJ) were measured using digital calipers. The roots of teeth were standardized to a length of 10 mm by cutting the root tip to simulate incomplete root formation when measured from the apex to the cementoenamel junction (CEJ). Endodontic access cavities were made using round bur in a high-speed handpiece. Peeso Reamers between #1 and #6 were introduced into the root canal until #6 pass freely out of the apex to simulate immature open apex. After instrumenting with Peeso reamers, the radicular dentin thickness was 2.5 mm. Further 703 carbide bur was used to obtain the remaining dentin thickness around 1 to 1.5 mm. The samples were then subjected to CBCT analysis to confirm the dentin thickness. Irrigation was done using 3 ml of 3% sodium hypochlorite and finally with 5 ml of 17% Ethylene diamine tetra acetic acid. Canals were restored with materials according to manufacturer's instructions.

The teeth assigned to four groups randomly (n=20) given as follows.

Group A: Control group

Group B: Biodentine (Septodont, Saint Maur des Fosses, France)

Group C: DiaRoot BA (BA (DiaDent Group International, Canada).

Group D: MTA-Angelus (MTA-A) (Angelus Solucoes Odontol´ogicas, Londrina, PR, Brazil).

In Group A- Control group, the immature tooth models were left unfilled without any reinforcement material. In Group B- Biodentine group, the liquid from container was olaced in capsule with powder and mixed for 30 seconds at 4000–4200 rpm. Condensation

was done = using pluggers. In Group C- Bio Aggregate, Bioaggregate powder was mixed according to manufacturers instructions(1 g powder with 0.38 ml of liquid). Teeth were restored using lentulospiral and condensed with pluggers. In Group D- MTA Angelus , the placement of white MTA-A was using a lentulo spiral and then condensation was done using pluggers. The coronal parts of teeth were covered with a moist cotton for 24 hours before permanent restoration is placed. The specimens were stored for three months until fracture resistance was tested in 100% humidity at 37∘C .

FRACTURE TESTING:

The surfaces of root were covered with a polyether impression material to mimic the periodontal membrane. The roots were mounted in self-curing resin. Each specimen was placed in a universal testing machine (Instron, Japan). The spade, which was used to apply the force to the specimen, was placed on the facial surface at 90 ° to the long axis of the tooth in a buccal/lingual direction at a point 3 mm above the cementoenamel junction to stimulate a traumatic blow on the middle third of the dental crowns . The samples were loaded at a speed of 1 mm /min untill the fracture occured. The peak load was recorded in newtons

STATISTICAL ANALYSIS:

SPSS 22.0 software (SPSS Inc, Chicago, IL) was used for statistical analysis. After completing the fracture test, the data were subjected to statistical analysis using 1-way analysis of variance with the Tukey post hoc test for multiple comparisons. The testing was performed at the 95% level of confidence ($P < .05$).

The results showed that

- Biodentine group had significantly high fracture resistance compared to other groups
- Bioaggregate group showed higher fracture resistance than MTA Angelus and control group.
- Control group showed the least fracture resistance and had statistically significant lower fracture resistance compared to other groups

CONCLUSION

Within the limitations of this study we conclude that Biodentine filled immature teeth have higher fracture resistance than Bio Aggregate and MTA Angelus. Further research is necessary to take advantage of these materials under clinical applications. Additional invitro, ex vivo, and invivo research must be conducted to evaluate the performance of these materials.

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