Comparative Evaluation of Fracture Resistance of Endodontically Treated Teeth With Furcal Perforations Of Various Sizes Restored With MTA And Biodentine – An In Vitro Study

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Abstract

Aim: The aim of this in vitro study was to evaluate the fracture resistance of endodontically treated teeth with furcal perforations of various diameters restored with MTA and Biodentine.

Materials and Methods: 32 freshly extracted mandibular molars were taken and split into 4 groups of 8 samples per group. Group A: 1 mm perforation repaired with MTA; Group B: 1 mm perforation repaired with Biodentine; Group C: 2 mm perforation repaired with MTA; Group D: 2 mm perforation repaired with Biodentine. Following biomechanical preparation, furcal perforations were simulated on all the teeth with the help of high-speed diamonds. They were then repaired using either MTA or Biodentine. All samples were subjected to fracture testing by using a Universal Testing Machine at a crosshead speed of 1 mm/minute till they fractured.

Results: Both the Biodentine groups should a greater mean fracture resistance than the samples repaired with ProRoot MTA but statistical analysis revealed that it was not of any statistical significance.

Conclusion: Biodentine can be considered as an excellent alternative to ProRoot MTA given its advantages over the former material such as faster setting time, easier workability and lack of discolouration potential.

Keywords: Biodentine, ProRoot MTA, Fracture Resistance, Furcal Perforations, Root Canal Treatment

Introduction

A root canal perforation has been defined by the American Association of Endodontists' Glossary of Endodontic Terms (2020) as a mechanical or pathologic communication between the root canal system and external root surface. They may occur due to a carious process, as resorptional defects or iatrogenic errors too. The prognosis of a perforation repair is highly dependent on many factors such as the time of occurrence, time relapse between the perforation and repair, microbial contamination, size and location of the perforation and mechanical properties and sealing ability of the repair materials used. A perforation repair material should be selected based on access to the perforation site and it must be biocompatible, bioactive and must provide an adequate seal while resisting the forces of dislodgement.[1-3] Perforations are iatrogenic mishaps which may occur at any time during the course of the endodontic treatment. They are a major reason for endodontic failure of teeth. As a consequence of such defects, a pathological communication between the root canal system and the periodontium is established which puts the overall result and success of the endodontic treatment in jeopardy. Additionally, there is also mechanical weakening of the root structure, trauma to the periodontal tissues and creation of a potential route for microorganisms to re-enter the root canal system which may lead to a lot of complications. This kind of damage ultimately results in extraction of the tooth due to compromised structural integrity and difficulty in achieving a good post endodontic seal.[4,5] Furcal perforations are those kinds of pathological communications which occur at the furcation region of the pulpal floor of a tooth, mainly in the mandibular molars. They have a much poorer prognosis than those occurring at the apical and middle thirds due to substantially greater risk of contamination from the external oral environment. Additionally, any delay in repairs may lead to further microbial contamination, subsequent chronic inflammatory onslaughts, ingrowth of granulation tissue through the defect and occurrence of bone lesions at the site of perforation all of which collectively endanger the prognosis of the tooth both mechanically and biologically. The overall support to a tooth is given by the combined action of the periodontal ligament (PDL) and alveolar bone. An intact PDL ensures that the occlusal loads are evenly transmitted to the bone and tooth movements occur under functional loads. Even with good repair of the perforation, there is a slight alteration in the biomechanical response of the tooth due to compromised tooth structure, bone and PDL at the furcal region. Furcal perforations result in a reduction in the supported root surface area and as a consequence, this leads to adverse effects on the overall stress distribution of root canal treated teeth.[6-8] Over the years, several perforation repair materials have been proposed to treat these defects successfully. Of all the materials used to seal a perforation, bioceramic materials have shown tremendous success in restoring these defects due to excellent physical properties and superior biocompatibility. Irrespective of what a manufacturer may claim, there are certain basic requirements which need to be met by these perforation repair materials which include adequate flexural and compressive strength, good biocompatibility, low cytotoxicity, osteogenic and cementogenic potential, good workability and economic feasibility. Mineral

Trioxide Aggregate (MTA) is one such frequently used bioceramic material which has been associated with high success rates. It was introduced at Loma Linda University, California in the year 1993 by Mahmoud Torabinejad and is formulated from a commercial Portland cement. It is a calcium silicate-based material known for its superior sealing ability and biocompatibility. It consists of tricalcium silicate, tricalcium aluminate, dicalcium silicate, calcium sulfate dihydrate and bismuth oxide. It has a pH of about 12.5 after setting which is the same as that of calcium hydroxide. It has shown tremendous results in large perforations with periodontal inflammation and is considered as a gold standard material for repair of perforations. Additionally, it has also been used in regenerative endodontic procedures, apexification, pulpotomies and as a pulp capping agent.[9,10] Although multiple calcium silicate-based materials have been introduced into the market, Biodentine is one such material which has managed to cling on to the spotlight for slightly over a decade now. It became commercially available in the year 2009, launched by the company “Septodont” and was specifically designed as a “Dentine replacement” material. It is a hydraulic cement developed to replace dentin which was targeted at vital pulp therapy and other applications which are similar to that of MTA.[11] These superior properties of Biodentine, as claimed by the manufacturer were tested against MTA which has been the gold standard perforation repair material since the late 1990s in an in vitro study where an attempt was made to evaluate and compare the fracture resistance of endodontically treated teeth with furcal perforations of various sizes restored with both of these materials.

Materials and Methods

Patients requiring extraction of mandibular molars due to periodontal purposes were selected for the study. These patients who reported to the Department of Oral and Maxillofacial Surgery of Bharati Vidyapeeth (deemed to be) University Dental College and Hospital, Pune were enrolled for the study and strict anonymization was observed while collecting the teeth. These teeth were then cleaned properly and stored at 4 degrees in physiological saline before using. Sample size estimation was done. Intact, non-carious and unrestored mandibular molars without any pulpal aberrations and well developed furcations without any resorptional defects were included and those with cracks, severely curved roots, fused roots and extra roots were excluded from the study. The samples were prepared in the Department of Conservative and Dentistry and Endodontics, Bharati Vidyapeeth Dental College and Hospital, Pune and fracture resistance was evaluated in Praj Metallurgical Laboratory, Pune.

Sample Size Estimation

Sample size was estimated under the following assumptions: Alpha error = 5%, beta error = 20%, reading in group 1= 0.8, reading in group 2= 0.2, common standard deviation = 0.42. The minimum required sample size was calculated (http://powerandsamplesize.com/Calculators/Compare-2-Means/2-Sample-Equality) to be 8. The minimum required sample size per group was thus set at 8.

Sample Preparation

32 mandibular molar teeth which were extracted due to periodontal reasons were chosen for this in vitro study. Teeth which were intact, non-carious, unrestored and without any previous endodontic treatment, resorptive defects or calcifications were chosen for this study. The

extracted teeth were first cleaned properly to remove any residual tissue tags and rinsed under running water after which they were stored using physiological saline. All the teeth were then sectioned at the level of the cementoenamel junction with the help of a diamond disk mounted on a straight handpiece under high speed.

Fig 1: Data Collection

Fig 2: Data Storage

Endodontic Treatment of The Samples

After disposing the sectioned coronal structure, with the help of a DG 16 Endodontic explorer (GDC), the canal orifices were located. A size 10 K-file (Mani) was inserted inside a canal till the tip of the file was just visible at the apex of the tooth. This procedure was done for all the teeth and all the canals and the working length was fixed at 1 mm short of this length for all the canals. A glidepath was prepared with the help of a 15 K- file (Mani) with gentle hand motions after which a rotary glidepath file, Easypath (Azure) which had an apical size of 0.14 mm and a taper of 4 % was used. An orifice opener, Sx (Dentsply, Sirona) was used to enlarge the orifices of all the canals before the working length was established with the rotary file (Easypath, 14 (4%) file) for coronal pre-enlargement and easier passage of the subsequent files. Initial irrigation was carried out with the help of 5.25% sodium hypochlorite (Hyposept, Sterilla) and normal saline. For all the mesial canals, after preparation of the glidepath, further instrumentation was carried out with Endostar E3 Azure files till an apical diameter of 0.25 mm and a taper of 4% owing to their narrower orientation than the distal canals. For teeth having a single distal canal, instrumentation was done with Endostar E3 Azure files till an apical diameter of 0.25 mm and a taper of 6% due to their wider orientation. For teeth having two distal canals, instrumentation was done for both the distal canals with Endostar E3 Azure files till an apical diameter of 0.25 mm and a taper of 4%. After each instrumentation before moving on to the next file, copious irrigation was done with 5.25% sodium hypochlorite solution to remove the debris collected within the canals. Finally, all the canals were rinsed with saline to wash off the final debris. Corresponding to the size (taper and apical diameter) to which the canals were instrumented, gutta percha cones (Dentsply, Sirona) were selected. A master cone radiograph was taken at this stage to confirm the quality of obturation. All the canals were dried with the help of greater taper (4% and 6%) paper points to make the canals fully dry. Paste A and paste B (base and catalyst) of AH Plus sealer (Dentsply, Mallifer) were taken in equal proportions before mixing (1:1) to achieve a homogeneous consistency. This step was then followed by mixing of the base and catalyst paste in a paper pad with the help of a metal spatula. The gutta percha cones were coated with the sealer after which they were placed inside the canals and sheared at the level of the orifice with the help of an obturation pen (Dentmark) and a plugger (30-70, Etchenem) to compact the gutta percha at the level of the orifice. The teeth were left undisturbed at 37°C for a period of 24 hours to ensure the set of sealer as specified by the manufacturer. Following the set of the sealer, all the 32 samples were randomly divided into 4 groups of 8 samples in each group according to the diameter of perforation and material used for repair.

Group A - 1 mm diameter with MTA – Endodontic treatment followed by sealing the furcal perforation of 1 mm diameter with MTA
Group B – 1 mm diameter with Biodentine – Endodontic treatment followed by sealing the perforation of 1 mm diameter with Biodentine
Group C - 2 mm diameter with MTA – Endodontic treatment followed by sealing the furcal perforation of 2 mm diameter with MTA
Group D – 2 mm diameter with Biodentine – Endodontic treatment followed by sealing the furcal perforation of 2 mm diameter with Biodentine

Creating The Furcal Perforations

Before splitting the samples into 4 groups of 8 samples each, all the 32 samples were first divided into two broad groups to make the 1 mm and 2 mm perforations. For making perforations of diameter 1 mm, a BR-31 bur (Mani) was used with a high-speed contra-angled handpiece (Waldent) in the centre of the pulpal floor until the bur came out through the furcal region. After this, a vernier calliper (Zhart) was used to verify the diameter of the perforation that was created. For making perforations of diameter 2 mm, an endo access bur (EA L10, Mani) was used at the centre of the pulpal floor until the bur came out through the furcal region. Since the endo access bur corresponded to a diameter of 1.9mm, a straight fissure bur was used under slow coastal speed and the diameter of 2 mm was verified with a vernier calliper. Prior to repairing the samples with the corresponding bioceramic material, a wet sponge was placed in the furcal areas of all the samples in order to help simulate the periapical area and to maintain a moist condition which would also aid in the setting of the repair materials since both MTA and Biodentine are hydrophilic in nature.

Fig 3: Sample After Creating The Furcal Perforation

Repair With MTA

ProRoot MTA was used for repair of 16 samples. The 1mm and 2 mm samples were repaired separately to avoid confusion in the grouping. The protocol for preparing MTA was as per the mixing instructions which were given by the manufacturer. One pouch of ProRoot MTA (Dentsply, Sironna) root repair material was opened and the powder was dispensed on to a mixing pad. The end of the liquid micro-dose ampule was pulled off and the contents were squeezed on the mixing pad next to the dispensed powder. The liquid was then slowly incorporated in the cement using the ProRoot MTA mixing stick and it was mixed for about one minute to ensure adequate hydration of all the powder particles until a wet sand consistency was achieved.[12]

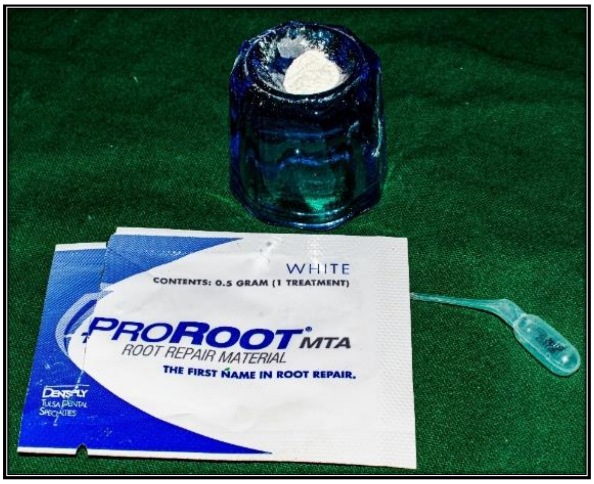

Fig 4: Pro Root MTA (Dentsply)

A curved MTA carrier (Waldent), 0.8 mm diameter was used to carry the mixed MTA to the perforation site. They were gently pushed to prevent extrusion outside the perforation site till the wet sponge area with a hand plugger (30-90) (Etchenem) to ensure complete coverage of the perforation site. The same procedure was followed for both the 1 mm and 2 mm samples till MTA was filled up to the pulpal floor at the same level as the obturated orifices.

Repair With Biodentine

Biodentine (Septodont) was used for repair of the remaining 16 samples. The 1 mm and 2 mm samples were placed separately to avoid confusion in the grouping. One Biodentine capsule was opened from the pack and it was gently tapped on its surface in order to loosen the powder inside. The capsule was then opened and placed on the white capsule holder from the kit. A single dose container of the liquid was then taken following which it was gently squeezed in order to force all the contents down the container. The cap was twisted to open the container after which 5 drops of liquid were poured inside the capsule. After closing the capsule, it was then placed on an amalgamator (COXO) which was set to a speed of 4000 rotations per minute for a period of 30 seconds.[13]

Fig 5: Biodentine (Septodont)

After mixing for 30 seconds, the capsule was opened and Biodentine was carried with the instrument supplied in the box. A hand plugger (30-90) (Etchenem) was used to condense the Biodentine over the perforation site till the wet sponge area. Mild condensation pressure was used to prevent extrusion of the material outside the perforation site and Biodentine was filled up to the pulpal floor at the same level as the obturated orifices. The same procedure was followed for both the 1 mm and 2 mm samples. After repairing all the samples with the respective bioceramic materials, a small piece of wet cotton was placed over the site of repair. The samples were then stored at 37°C for a period of 1 month to ensure complete setting of the biooceramic repair materials. One month later, the cotton was removed after which a small coronal covering was made with a temporary restorative material (NeoTemp) to cover the orifices.

Fracture Testing

The samples were taken to Praj Metallurgical laboratory for testing the fracture resistance with the help of a universal testing machine (Unitest -10 ACME Engineers, India). It was a computerized, software-based device with an accuracy of ±1%. All the teeth were first mounted in acrylic blocks (DPI Self cure acrylic) of 22.5 cm diameter and 13 cm height which were made from standardized moulds.

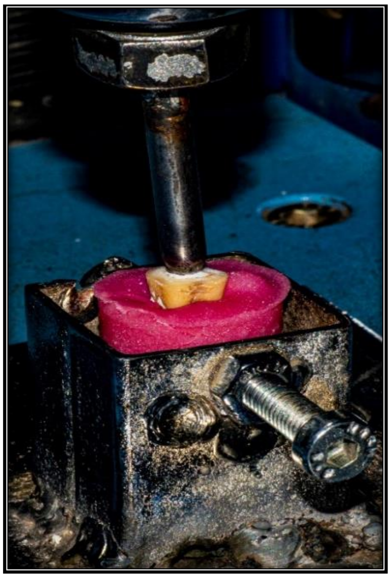

Fig 6: Sample Placed In Universal Testing Machine

The teeth were inserted till a level in the self-cure acrylic where the furcations were slightly visible. A metal indenter of 5 mm diameter was chosen and each of these samples were mounted on the universal testing machine. With a crosshead speed of 1 mm/minute, compressive forces were applied on the temporary restorative material vertically, parallel to the long axis of the teeth with the metal indenter until the teeth fractured. After noting down the fracture resistance in all the groups, the obtained data was subjected to statistical analysis. After each step, photographs were taken with the help of Nikon D3300 DSLR camera with an 18-55 standard lens and a Tamron 90 MM macro lens in the manual mode.

Fig 7: Fracture of The Sample Marking The End Of The Test

Statistical Analysis

Descriptive and inferential statistical analyses were carried out in the present study. Results on continuous measurements were presented on Mean ± SD. Level of significance was fixed at p=0.05 and any value less than or equal to 0.05 was considered to be statistically significant. Student t tests (two tailed, unpaired) was used to find the significance of study parameters on continuous scale between two groups. Analysis of variance (ANOVA) was used to find the significance of study parameters between the groups (Inter group analysis). Further post hoc analysis was carried out if the values of ANOVA test were significant. The Statistical software IBM SPSS statistics 20.0 (IBM Corporation, Armonk, NY, USA) was used for the analyses of the data and Microsoft word and Excel were used to generate graphs, tables etc**.**

Results

Intergroup analysis using ANOVA was done to compare all the four groups and it was seen that both the biodentine groups showed greater fracture resistance than the corresponding MTA groups but this difference was not of statistical significance (F=1.051) (P=0.161). This was followed by Tukey's Post Hoc test which also revealed that there were no statistically significant differences between the groups. This was followed up by intragroup analysis by using unpaired t tests between each of these groups. It was seen that group A had a lower mean fracture resistance (895 N) than group B (1315 N), group C had a lower mean fracture resistance (1115.813 N) than group D (1148.813 N). Among the same bioceramic groups, it was seen that group A had lower fracture resistance (895 N) than group C (1115.813 N) and that group B had a higher fracture resistance value (1315 N) than group D (1148.813 N). It should be noted that none of these intragroup comparisons were of any statistical significance either.

Group	N	Mean	Std. Deviation	F value	P value
Group A	8	895.000	310.3721		
Group B	8	1315.000	549.4967		
Group C	8	1115.813	246.6106	1.851	0.161
Group D	8	1148.813	237.8152		
Total	32	1118.656	373.5391		

Table 1: Comparative evaluation of fracture resistance in terms of {Mean (SD)} of endodontically treated teeth with furcal perforations of various sizes restored with MTA & Biodentine using ANOVA test

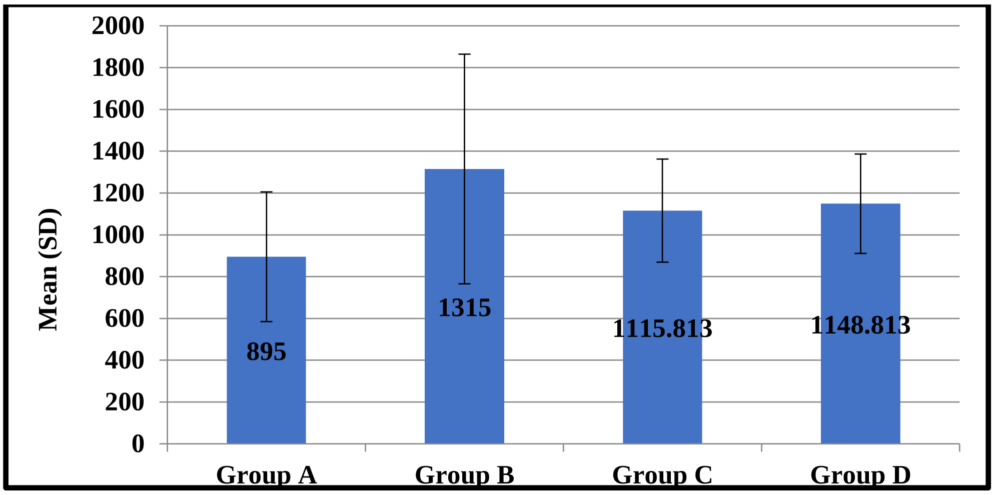

Fig 8: Comparative evaluation of fracture resistance in terms of {Mean (SD)} of endodontically treated teeth with furcal perforations of various sizes restored with MTA & Biodentine using ANOVA test

Discussion

The primary goal of endodontics is to achieve proper removal of infected pulp tissue, debris, micro-organisms and their by-products and maintain a good hermetic seal by synergistically using disinfectants and irrigants along with adequate instrumentation of the canal walls. Success of an endodontic treatment is dictated by prevention of recontamination of the root canal space following the process of disinfection and instrumentation. Molars are the main stress bearing areas of the dentition and mandibular molars are effectively placed in a position to withstand such high forces of mastication. Furcation area of teeth, especially posterior teeth contribute greatly towards the fracture resistance of a tooth and is an extremely critical area. Perforations in the furcal areas are piercings or unintentional opening of the pulpal floor and an injury which opens towards the periodontium through this defect.[14] Early diagnosis of furcal perforations is extremely crucial to the long-term prognosis of the affected tooth. Sudden profound bleeding or pain during instrumentation or post-space preparation of the root canals need to be taken as a warning sign to check the integrity of the pulpal floor carefully. Presence of blood on paper points especially at the coronal or middle thirds may also be indicative of such a mishap. In the present study, two different perforation groups of 1 mm diameter and 2 mm diameter were chosen. Furcal perforations can be classified as very small perforations (less than or equal to 1 mm), small perforations (2-3 mm) and large perforations (greater than 3 mm). In this study, it was decided to stick with 1 mm and 2 mm samples because a pilot study done with 3- and 4-mm diameters revealed that apart from the pulpal floor, the defect also had involved a considerable area of the root canal space itself which would make this study far less standardized.[15] For the simulation of iatrogenic perforations, two burs were used for standardizing the perforation diameters (1 mm and 1.9 mm) which were the BR – 45 and EA L 10 burs (MANI). The former was a round bur and the latter was an endodontic access bur. Remaining 0.10 mm in the 2 mm group was achieved by using a straight fissure bur at coastal speed and checking the dimension with a vernier calliper. These are routinely used for endodontic access cavity preparation depending on the clinician's preference and are aggressive cutting burs. Endo Z and non-end cutting burs were not used as they do not have a cutting edge. Ever since the inception of MTA in the year 1993, its applications have broadened consistently and extensive research has been conducted in improving its properties to suit various clinical scenarios where calcium hydroxide was used. It has various applications such as perforation repair and retrograde filling material, pulp capping agent, pulpotomies, repair of external and internal root resorptions, as an obturating material and for apexification and regenerative endodontic procedures. Calcium hydroxide is formed as a by-product of MTA which leeches out into the solution, dissociaing into calcium and hydroxide ions. This calcium ion forms an area of necrosis after coming in contact with the surrounding tissues, all of which leads to carbon dioxide formation giving rise to calcite crystals (calcium carbonate) which serves as the core of calcification. This resulting alkalinity of the medium stimulates the tissue around it to produce a glycoprotein, fibronectin. Fibronectin along with the calcite crystals help in forming type 1 collagen and along with calcium, leads to the process of mineralization.[16,17] Biodentine (Septodont, Saint-Maur-des-Fossés, France) was introduced in the market as a dentine replacement material. Being a hydraulic intra-coronal calcium silicate cement, its applications were specifically targeted at vital pulp therapies. It is a tricalcium silicate based and aqueous material which additionally has certain reaction modifiers which make it a type 4 bioceramic cement.[68] It consists of a powder and liquid, both of which arrive are available as a capsule and vial. Apart from the main components, a hydro-soluble polymer is additionally included in the liquid. This is organic in nature which is why it cannot be detected with X-ray fluorescence methods. According to the manufacturer's instructions, 5 drops from the liquid vial are added on to the powder particles inside the capsule which are then agitated mechanically at 4000-4500 RPM in an amalgamator for 30 seconds in order to achieve a homogeneous mixture ready for use.[13,18] After Biodentine sets, there is a marked increase in its compressive strength which goes up to 200 MPa from 100 MPa in the first hour after setting. This compressive strength continues to improve with time over a span of several days until it reaches 300 MPa following one month. This 300 MPa compressive strength is comparable to natural dentin which is 297 MPa. Grech L et al., studied Biodentine's compressive strength and showed that it had the highest compressive strength compared to all other materials owing to its low water/powder ratio. All of the samples in the present study were subjected to evaluation of fracture resistance under compressive forces one month following placement of the bioceramic materials even though these materials set way earlier than this stipulated time period. This longer wait period was to take full advantage of this particular property of Biodentine. [19-21] Due to the overall dwindling number of studies which exist on Biodentine, particularly those which highlighted its physical properties and compared it against other bioceramic materials, in this study decided the fracture resistance of endodontically treated teeth with furcal perforations were compared and additionally 2 different diameters of perforations were included to see if there was an edge of either of the materials used over the other. Literature has shown that in general Biodentine seems to exhibit superior physical and mechanical properties compared to MTA. However, there is a lacuna in the present literature in that there are no studies which evaluated the fracture resistance of endodontically treated teeth with furcal perforations repaired with MTA and Biodentine which is why it was decided to explore this aspect of both of these materials used routinely in such cases to find out if there was a difference which could be of clinical significance. Since teeth with furcal perforations have much less dentinal volume compared to whole teeth and furcation areas are considered to be critical zones of endodontically treated teeth, it is a now a universal fact that such teeth are bound to have a much lesser fracture resistance compared to teeth without perforations. This was the reason that a control group was excluded in this study and only test groups were compared. The present study compared the fracture resistance of endodontically treated teeth with furcal perforations of diameters 1 mm and 2 mm repaired with MTA and Biodentine using a Universal Testing Machine. Perforation size is one of the factors to be taken into consideration which affects repair. Usually, small perforations are more favourable towards direct and immediate restoration as there is a lower chance of any periodontal failure or epithelial proliferation at that area. In cases where a repair material contacts a larger surface area of the periodontium, the prognosis is unclear due to inflammatory stimulation which may or may not propagate to the adjacent tissues.[22,23] This study showed that among the 1 mm perforation groups, Biodentine group had a greater mean fracture resistance of 1315 N compared to the MTA group which had a mean fracture resistance of 895 N. Among the 2 mm perforation groups, the Biodentine group once again had a slightly greater mean fracture resistance of 1148.8 N compared to the MTA group which had a mean fracture resistance of 1115.8 N. This greater fracture resistance in both the perforation groups is in line with the manufacturer claims and a few studies which state that Biodentine has shown to have a greater flexural and compressive strength in general which is closer to that of natural dentin which is not the case with ProRoot MTA. However, it is worth noting that even though both the Biodentine groups showed a greater fracture resistance, neither of these values were of statistical significance. [19-21] Dental material analysis has shown that any material which has the same elasticity as that of natural dentin can reinforce weak roots. This holds true in in the present study as both the Biodentine groups showed a higher fracture resistance as the elasticity of Biodentine is closer to that of natural dentin. However, the present study cannot truly support this statement as Biodentine was used to repair furcal perforations of teeth which contained only healthy roots. Although MTA is the material of choice for furcal perforation repairs, there are a few studies which indicate that MTA weakens the dentin.[24-26] Askerbeyli Ors et al., did a finite element analysis evaluating different sizes of furcal perforations on the biomechanical response of mandibular molars. It was seen that the different sizes of furcal perforations taken in their study affected the accumulation and distribution of stresses which were generated within the models and that samples with larger furcal perforation diameter treated with MTA may be associated with an increased risk of fracture. This was the reason we had decided to go with perforation groups with different diameters of 1 mm and 2 mm. The results of our study in the MTA group however, were not in agreement of this above-mentioned study in that the 1 mm samples (895 N) had a considerably lower fracture resistance compared to the 2 mm samples (1115.8N) repaired with MTA even though the results were not statistically significant. This could be attributed to uneven distribution of data as tooth volumes could not be standardized in our study even though the perforations were. Another thing to be kept in mind is the difference in testing conditions. However, in the Biodentine groups, the 1 mm samples showed a lesser risk of fracture (1315 N) compared to the 2 mm samples (1148.8 N) even though the data wasn't statistically significant. These findings were in agreement of the above-mentioned study.[27] Use of Bioceramic materials in the field of endodontics has radically transformed the way perforations are viewed today. The number of furcal perforation repair cases have also increased exponentially over the years due to the ease of availability of these repair materials which has improved the prognosis of many of the cases which would have otherwise been indicated for extraction due to superior predictability of repair in such cases because of these materials. Introducing MTA into the dental market was a huge breakthrough in the history of dental material sciences and since then, a lot of improvisations have been made to maximize the benefits of this material. To overcome the limitations of MTA, Biodentine was introduced in the market. Both MTA and Biodentine are excellent perforation repair materials. Biodentine is however relatively easier to manipulate, has lower cost and sets very quick compared to MTA. Manufacrturers of Biodentine also claim that it has superior compressive and flexural strength. These properties along with excellent bioactivity and biocompatibility make this material a strong competitor and a potential replacement of ProRoot MTA as the new age gold standard furcal perforation repair material. There is still a lack of sufficient long-term clinical observational studies with long follow-up periods which is why it is still difficult to concretely state that either of these materials are superior.

Conclusion

Within the limitations of this current in vitro study, it was concluded that

- Fracture resistance of endodontically treated teeth with furcal perforations of diameter 1 mm repaired with Biodentine was greater (1315 N) compared to those repaired with MTA (895 N)
- Fracture resistance of endodontically treated teeth with furcal perforations of diameter 2 mm repaired with Biodentine was greater (1148.8 N) compared to those repaired with MTA (1115.8 N)
- Since none of the obtained results were of any statistical significance, it cannot be concluded that either of these materials were superior when it comes to furcal perforation repair at least from the results of this in vitro study
- Owing to the multiple disadvantages of ProRoot MTA like difficulty in manipulation, very slow setting time, difficult workability, high cost and potential to discolour the tooth structure, Biodentine can definitely be considered as an excellent alternative to ProRoot MTA given its obvious edge over MTA in many aspects and particularly its potential to develop superior mechanical properties over time, easier handling

References

1. Farzaneh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study. Phases I and II: Orthograde retreatment. J Endod 2004; 30:627-33.
2. Bargholz C. Perforation repair with mineral trioxide aggregate: a modified matrix concept. Int Endod J 2005; 38:59-69.
3. Nazari KM, Aghili H, Rashed AM, Zahedpasha S, Moghadamnia A. A comparative study on sealing ability of mineral trioxide aggregate, calcium enriched cement and bone cement in furcation perforations. Minerva Stomatol 2014; 63:203-10.
4. G. S. Heithersay, "Invasive cervical resorption following trauma," Australian Endodontic Journal, vol. 25, no. 2, pp. 79– 85, 1999.

5. Saed SM, Ashley MP, Darcey J. Root perforations: aetiology, management strategies and outcomes. The hole truth. Br Dent J. 2016 Feb 26;220(4):171-80. doi: 10.1038/sj.bdj.2016.132. PMID: 26917303.
6. Natali AN, Pavan PG, Scarpa C (2004) Numerical analysis of tooth mobility: formulation of a nonlinear constitutive law for the periodontal ligament. Dental Materials 20, 623-9.
7. Krupp C, Bargholz C, Brusehaber M, Hulsmann M (2013) Treatment outcome after repair of root perforations with mineral trioxide aggregate: a retrospective evaluation of 90 teeth. Journal of Endodontics 39, 1364-8.
8. Mente J, Leo M, Panagidis D, Saure D, Pfefferle T (2014) Treatment outcome of mineral trioxide aggregate: repair of root perforations-long-term results. Journal of Endodontics 40, 790-6.
9. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review—part III: clinical applications, drawbacks, and mechanism of action. Journal of endodontics. 2010 Mar 1;36(3):400-13.
10. Mente J, Leo M, Panagidis D, Saure D, Pfefferle T. Treatment outcome of mineral trioxide aggregate: repair of root perforations—long-term results. Journal of endodontics. 2014 Jun 1;40(6):790-6.
11. S Askerbeyli Örs, H Aksel, S Kucukkaya Eren, A Serper Effect of perforation size and furcal lesion on stress distribution in mandibular molars: a Finite Element Analysis. International Endodontic Journal, September 2018
12. Dentsply. Pro Root MTA (mineral trioxide aggregate)root canal repair material. 2003;2017:2–6.
13. Septodont. Biodentine - Instruction. 2015; MISC Biodentine/Septodont, instruction card for usage and properties, http://www.septodontusa.com/sites/default/files/ Biodentine%20IFU.pdf.
14. Bargholz C. Perforations. In: Hülsmann M, Schäfer E, editors. Problems in endodontics. Etiology, diagnosis and treatment. Berlin: Quintessence; 2009. p. 385–400.
15. Bortoluzzi E, Souza E, Reis J, Esberard R, Tanomaru-Filho M. Fracture strength of bovine incisors after intra-radicular treatment with MTA in an experimental immature tooth model. Int Endod J 2007; 40:684-91.
16. Torabinejad M, Watson TF, Pitt Ford TR. Sealing ability of a mineral trioxide aggregate when used as a root-end filling material. J Endod. 1993; 19:591–5
17. Holland R. Histochemical response of the pulp of dogs to capping with mineral trioxide aggregate or a calcium hydroxide cement. Dent Traumatol. 2001;17: 163–6.
18. Camilleri J, Sorrentino F, Damidot D. Investigation of the hydration and bioactivity of radiopacified tricalcium silicate cement, biodentine and MTA angelus. Dent Mater. 2013;29(5):580–93.
19. Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I. Physiochemical basis of the biologic properties of mineral trioxide aggregate. J Endod. 2005;31(2):97-100.
20. O’Brien W (2008) Dental Materials and their Selection.
21. Grech L, Mallia B, Camilleri J. Investigation of the physical properties of tricalcium silicate cement-based root-end filling materials. Dent Mater. 2013;29(2):20-28.

22. Parveen S, Hossain M, Sheikh MA, Abdin MJ. Repair of iatrogenic furcation perforation with glass ionomer cement. Bangabandhu Sheikh Mujib Med Univ J 2018; 11:70-4.
23. Mente J, Leo M, Panagidis D, Saure D, Pfefferle T. Treatment outcome of mineral trioxide aggregate: repair of root perforations—long-term results. J Endod 2014; 40:790-6.
24. Li L-L, Wang Z-Y, Bai Z-C, Mao Y, Gao B, Xin H-T, et al. Three-dimensional finite element analysis of weakened roots restored with different cements in combination with titanium alloy posts. Chin Med J 2006; 119:305-11.
25. Main C, Mirzayan N, Shabahang S, Torabinejad M. Repair of root perforations using mineral trioxide aggregate: a long-term study. J Endod 2004; 30:80-3.
26. White JD, Lacefield WR, Chavers L, Eleazer PD. The effect of three commonly used endodontic materials on the strength and hardness of root dentin. J Endod 2002; 28:828-30.
27. S Askerbeyli Örs, H Aksel, S Kucukkaya Eren, A Serper Effect of perforation size and furcal lesion on stress distribution in mandibular molars: a Finite Element Analysis. International Endodontic Journal, September 2018.