

A comparative analysis of sealing ability and microleakage of different materials as a furcation repair material: An ex-vivo study.

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Abstract: Perforation of the root canal system is the second large cause of root canal failure. Failure to seal the perforation defect permits rapid break-down of the periodontium and tooth loss. Hence sealing the defect is paramount. The study was aimed to comparatively analyse the sealing ability and microleakage of different materials as a furcation repair material. **Material and method:** In current study, Mineral trioxide aggregate (MTA) Angelus, Biodentine, and RMGIC were selected. Eighty mandibular molars were randomly divided according to the material used for perforation repair. Group I- (left unsealed/not repaired) control, Group II - Biodentine, Group III - MTA Angelus, Group IV - RMGIC. All samples were subjected to orthograde and retrograde methylene blue dye challenge followed by dye extraction with 65% nitric acid. Samples were then analyzed using UV Spectrophotometer. **RESULT:** After One Way Analysis of Variance, LSD post hoc test was applied for pairwise comparison it shows highly significant differences ($P < 0.05$) among tested materials. **Conclusion:** Significantly higher values of microleakage in RMGIC than Biodentine, MTA and Significant higher values of microleakage in Positive control than Biodentine, MTA, RMGIC. Hence forth the above study showed that Biodentine shows maximum sealing ability and least microleakage when compared with MTA and RMGIC.

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I. Introduction

Maintaining the integrity of the natural dentition is important for proper function and natural esthetics. Endodontic therapy can play a vital role in achieving this goal. Occasionally mishaps occur during endodontic treatment. One of them is perforation of root canal wall, which can significantly impact the long-term prognosis of the tooth. Furcation perforation refers to a mid-curvature opening into the periodontal ligament space and is the worst possible outcome in root canal treatment¹. It has been reported that perforations were the second greatest cause of failure². To prevent bacterial contamination, perforations should be repaired as quickly as possible with a biocompatible material³. Furcal repair in teeth Has become more essential than extraction, to prolong the longevity of the tooth. An ideal perforation repair material should provide an adequate seal, be biocompatible, not affected by blood contamination, not be extruded during condensation, bactericidal, induce bone formation and healing, radiopaque, induce mineralization, cementogenesis and easy in manipulation and placement⁴. Several materials have been proposed for sealing of perforations. These materials include Zinc-oxide Eugenol cement (Intermediate Restorative Material, Super- Ortho Ethoxy Benzoic Acid), Glass ionomer cement, Resin cements, Resin - modified Glass ionomer cement and Mineral Trioxide Aggregate. However, the divergent outcomes have demonstrated that so far no material has satisfied all the ideal requirements⁵.

The correction of furcation perforation can be achieved using intracoronal or surgical approach¹. The non-surgical coronal approach involves the immediate placement of a repair material in the perforation to avoid potential bacterial infection of the wound site. The major difficulty with conventional repair procedures is the extrusion of the filling material into the periodontal space, and interference with periodontal reattachment. Materials like Cavit, Zinc phosphate cement, calcium hydroxide, gutta percha, amalgam, indium foil, dentin chips are used to manage furcation perforation. Recently calcium sulfate and hydroxylapatite have shown the occurrence of bone repair. These materials are stable, biocompatible, readily available, easily sterilized and its rapid rate of resorption coincides with the rate of new bone growth.

Today, most preferred furcation repair materials are bioactive materials like Mineral Trioxide Aggregate and Biodentine. Despite the favorable properties of MTA that supports its clinical use, it has several clinical drawbacks such as prolonged setting time, difficult handling characteristics, and potential discoloration⁶.

Hence, in an attempt to modify the properties of MTA and to overcome the shortcomings, a variety of new Calcium-silicate based materials have been formulated which includes Biodentine, BioAggregate, RetroMTA, and EndoSequence root repair material. Biodentine (Septodont, France) is a high purity calcium-silicate based dental material composed of tricalcium silicate; calcium carbonate, zirconium oxide, and water-based liquid containing calcium chloride (CaCl₂) as the setting accelerator and water-reducing agent. Biodentine is recommended for use as a dentin substitute and an endodontic repair material because of its good sealing ability, high compressive strengths, short setting time^{7,8}, biocompatibility, bioactivity and biomineralization properties⁹.

Resin modified Glass Ionomer Cement is a powder liquid system. Powder is composed of silica, alumina, aluminium fluoride, calcium fluoride, sodium fluoride, aluminium phosphate and liquid consisting of polyacrylic acid, tartaric acid and water. When used as perforation repair material, Alhadainy and Himel found that light-cured glass ionomer cement exhibited a better seal than amalgam or Cavit when used for furcation perforations repair. A subsequent study suggested that light-cured glass ionomer cement has superior sealing ability compared to chemically cured glass ionomer cement. Overall it is shown that Glass Ionomer Cement exhibits a greater sealing potential than conventional materials due to its adhesion property.

II. Material And Methods

The present in-vitro study of sealing ability with dye extraction method was carried out at the Department of Conservative and Endodontics, Jaipur Dental College, Jaipur, Rajasthan, India.

Study Location: Department of Conservative and Endodontics, Jaipur Dental College, Jaipur, Rajasthan, India.

Study Duration: November 2016 to November 2017.

Sample size: 80 teeth.

Selection method: Eighty freshly extracted intact permanent first and second mandibular molars, free of caries, cracks, fractures, restorations with non-fused and non-hypoplastic teeth were selected from extracted teeth. Human teeth used for research are to be treated as potential source of blood-borne pathogens, according to the United States Occupational Safety and Health Administration (OSHA). The centre for disease control and prevention has adopted guidelines for infection control of extracted teeth for research and teaching. Thus, the teeth were cleaned of any tissue remnants on the roots, plaque and calculus with periodontal scalers and were stored in 10% formalin for disinfection for 7 days and subsequently stored in 0.9% normal saline solution.

Inclusion criteria:

Intact permanent mandibular molars extracted purely for periodontal reasons

Exclusion criteria:

1. Teeth with presence of any type of carious lesions were discarded.
2. Teeth with restorations or any defects were excluded from the study.
3. Teeth having improper anatomy, hypoplastic and fractured teeth were discarded.
4. All teeth were inspected for the presence of cracks. Those with apparent cracks were excluded from the study.
5. Teeth with fused roots were excluded from the study.

III. Procedure methodology

Specimen Preparation

Molars were marked 3mm apical and coronal of the furcation area with the help of Williams probe by a black marker. Tooth were amputated by high speed diamond disc according to the markings. Endodontic access cavity were made in every molar using high speed Round bur no.4 (Mani DIA-BURS BR-41) followed by Endo access bur no.2 (Maillefer Dentsply, Switzerland) for lateral extension and finishing of cavity wall, with use of high speed air turbine Handpiece (Being Foshan, China) and the root canal orifices were located.

Sticky wax was placed over the orifices of each canal and the sectioned root surface including pulpal floor. It was then coated with two successive layers of nail varnish to increase the marginal seal. To ensure each perforation was centered between the roots, a black marker pen was used to mark the location of the defect. Artificial perforation of 2mm in diameter was created using a round diamond bur mounted on a high-speed handpiece with air water coolant. Then the molars were divided into three experimental and positive groups as follows:

Table 2: DISTRIBUTION OF SPECIMENS INTO VARIOUS GROUPS

Groups	No. of samples	Sample no.	Material used for furcation repair	Company
I	20	P1 – P20	Positive control	-
II	20	B1 – B20	Biodentine	Septodont Saint-Maur-Des-Fosses Cedex, France
III	20	M1 – M20	MTA Angelus	Angelus
IV	20	G1 – G20	GC Gold Label 2LC Light Cured Reinforced Glass Ionomer Restorative (RMGIC)	GC Corporation, Tokyo, Japan

Molars were kept containing cotton moistened with saline in an attempt to stimulate clinical conditions and access preparation was sealed with a temporary restoration were allowed to set for 24 h.

Perforation Repair

Group 1: Teeth left unrepaired.

Group 2: Biodentine

Biodentine capsule was taken and it was gently tapped on a hard surface to loosen the powder. The capsule was opened and the powder was placed on the glass slab. The single dose container of liquid was detached and gentle tap on the sealed cap to force all the liquid down the container. The cap was twisted to open it. Care was taken so that no drop of liquid falls out of the single dose container. 5 drops from the single-drop container were poured onto the powder over glass slab. Mixing was done for 30 seconds with the plastic instrument supplied in the box and was checked for the material's consistency. Biodentine was carried to the site of perforation with the help of MTA carrier (GDC) and then was condensed. Any excess material was removed with an endodontic spoon excavator(API). A moist cotton pallet was placed and access preparation was sealed with a temporary restoration for 24 hours.

Group 3: MTA Angelus

MTA Angelus powder was placed onto a glass slab. The sterile water ampoule was opened and water was mixed slowly into MTA Angelus powder with a plastic spatula. The tube of MTA endo carrier (Dentsply Maillefer, Switzerland) was filled with the MTA Angelus material by lightly tapping the carrier device into the premixed MTA Angelus material. The carrier was positioned over the perforation area to be repaired. Hand pressure was applied to the carrier to express the MTA Angelus material from the MTA tube. MTA was condensed. Any excess material was removed with an endodontic spoon excavator(API). A moist cotton pallet was placed and access preparation was sealed with a temporary restoration for 24 hours.

Group 4: GC Gold Label 2LC Light-Cured Reinforced Glass Ionomer Restorative

One scoop of powder and two drops of liquid were dispensed on a mixing pad. Powder was divided into two half. The liquid was spread out into a thin layer (about 3mm) with plastic spatula. Half of the powder was mixed onto the liquid with lapping strokes for 10 to 15 seconds. The remaining powder was pulled in and mixed thoroughly to a glossy consistency. Care was taken not to exceed the total mixing time by 20-25 seconds. The cement was carried to the preparation site using a plastic filling instrument (GDC). Light curing was done for 20 seconds using a light curing device. All the teeth in each group were allowed to set for 24 hrs.

Dye Extraction Microleakage Evaluation

Molars were then placed in the Petri dishes according to each group containing 2% Methylene blue dye(MERCK). The dye was also applied inside the access cavity of all samples for 24 hours. Molars were placed under running tap water for 30 minutes to remove all residues of methylene blue and then nail varnish was removed with a Parker blade #15 (GLASSVAN, India) and polishing discs (Soft lex, 3M-ESPE, USA). Then molars were placed in 1mL of concentrated (65wt%) Nitric acid (Qualigen, India) for 3 days. Vials were centrifuged at 3500 rpm for 5 minutes. Two hundred mL of the supernatant from each samples were then analyzed in an UV Spectrophotometer at 550nm wavelength with concentrated nitric acid as a blank and readings were recorded as absorbance units.

Statistical analysis

Statistical analysis was performed with SPSS software package (version 20.0). Data were collected and analyzed by using variance test (One-Way ANOVA) and Tukey tests to test for any significance difference between the groups. The mean difference was significant at the 0.05 level.

IV. Result

Table no 1:Shows absorbance value of each sample

SAMPLE	GROUP I (POSITIVE CONTROL)	GROUP II (BIODENTINE)	GROUP III (MTA Angelus)	GROUP IV (RMGIC)
1.	0.2215	0.163	0.161	0.236
2.	0.3005	0.097	0.172	0.187
3.	0.2975	0.081	0.184	0.192
4.	0.309	0.0955	0.179	0.136
5.	0.35	0.164	0.163	0.26
6.	0.368	0.163	0.140	0.2135
7.	0.4055	0.166	0.1655	0.259
8.	0.2325	0.120	0.1205	0.231
9.	0.284	0.161	0.174	0.249
10.	0.401	0.1296	0.128	0.1595
11.	0.2875	0.108	0.109	0.205
12.	0.313	0.129	0.129	0.192
13.	0.498	0.1355	0.135	0.250
14.	0.328	0.129	0.096	0.2425
15.	0.246	0.1085	0.1085	0.236
16.	0.35	0.1203	0.143	0.245
17.	0.297	0.162	0.175	0.290
18.	0.2214	0.082	0.162	0.193
19.	0.1254	0.134	0.127	0.326
20.	0.284	0.122	0.140	0.201

Table no2:Mean standard deviation, minimum and maximum values of microleakage (dye absorbance) in different groups.

GROUPS	MICROLEAKAGE(DYE ABSORBANCE)		
	Mean ±SD	Minimum	Maximum
Positive control (n=20)	0.323±0.073	0.222	0.498
Biodentine (n=20)	0.130±0.028	0.081	0.165
MTA Angelus (n=20)	0.144±0.023	0.096	0.181
RMGIC (n=20)	0.223±0.030	0.260	0.260

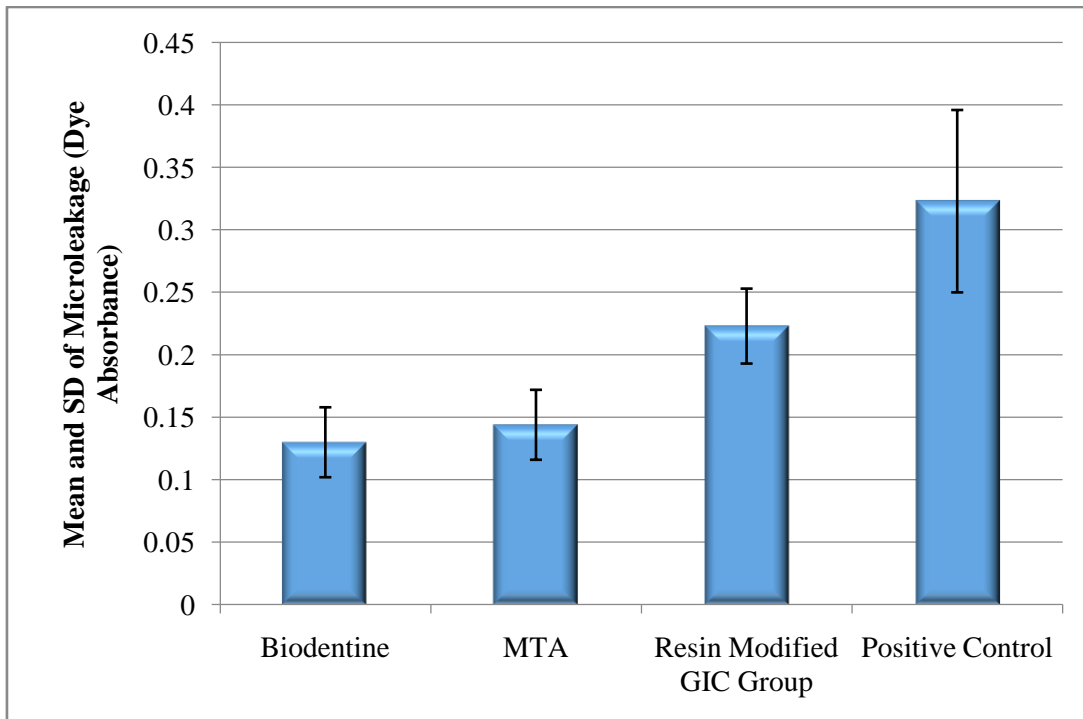


Table no3: pairwise comparison of groups for microleakage (dye absorbance) using lsd post hoc test

Comparison groups	Mean difference	P value
Biodentine and positive control	-0.193	0.000<(0.001), Significant Difference
Boidentine and MTA	-0.014	0.357(>0.05), Not Significant
Biodentine and RMGIC	-0.093	0.000<(0.001), Significant Difference
MTA and Positive control	-0.179	0.000<(0.001), Significant Difference
MTA and RMGIC	-0.080	0.000<(0.001), Significant Difference
RMGIC and Positive control	-0.100	0.000<(0.001), Significant Difference

After One Way Analysis of Variance, LSD post hoc test was applied for pairwise comparison it shows that:

1. Significantly higher values in RMGIC than Biodentine, MTA.
2. Significant higher values in Positive control than Biodentine, MTA, RMGIC

Not significant difference was found as-No significant difference between Biodentine and MTA Angelus. They both are same for microleakage.

V. Discussion

The integrity of natural dentition should be maintained for functional esthetic demands. The advancements in the technology and materials in different specialties of dentistry have made this possible. Among them, endodontics has emerged as one of the most popular branches of dentistry. In recent years, there has been an increased awareness among people to save their natural teeth. But each endodontic procedure has a variable degree of inherent risk.

Main cause of root canal failure is the clinician's inability to eliminate intraradicular microorganism from the infected root canal and endodontic mishaps. They depend upon many factors such as aberrant root canal anatomy, canal calcification, anomalous root shapes, severe root curvatures, choice of instruments and materials, type and quality of irrigant solution used, methods of performing treatment, experience of the operator etc. the combination of endodontic mishaps and infection can lead to permanent failure. Therefore, the thorough knowledge of prevention and management of such mishaps that Can occur during endodontic treatment will encourage reflection of the safe and prudent practice of endodontics. With the evolution of endodontics, uses of improved instruments and equipment's and innovative techniques can lead to reduce endodontic accidents but still they are not inevitable.

Most common endodontic mishaps such as perforation during access cavity preparation, file fracture, zipping, canal transportation, ledging, sodium hypochlorite accidents. Perforation create undesirable communication between the root canal system and the periodontium. Perforations may be iatrogenic or pathological. Iatrogenic perforations may be furcal perforation, apical periodontitis, lateral perforations, perforation created during post space preparation. According to Ingle, perforation is the second most common reason for endodontic failure and this accounts for 9.6% of all endodontic failure. During the non surgical retreatment procedures, perforation were found to be present 7-12% of the previous endodontic treatment.

According to Kvinnsland et al, 53% of iatrogenic perforations occur during insertion of posts, the remaining 47% are induced during routine endodontic treatment. Among these 47%,high percentage of perforation of perforations occur in furcation areas of multi rooted teeth when removing of dentin from the chamber floor while searching for canals. Other causes of furcal perforation are anatomic variations of tooth, inaccessibility of the tooth and inexperience of the operator.

The success of the furcation repair is always dependent on the effective seal between the root canal and the periodontal ligament. This can be achieved by a suitable material which should stop the microleakage and communication between the tooth and periodontal ligament. To obtain success, the perforation repair material should ideally result in formation of new bone, periodontal ligament and cementum. Previous studies have shown that cementogenesis is a vital process in dentoalveolar formation and the newly formed cementum acts a biological barrier against the spread of microbial irritants within the root canal system¹⁰.MTA and Biodentine™ are capable of causing complete regeneration of the adjacent dentoalveolar tissue in permanent teeth and are hence used in furcal perforation repairs¹¹.

The perforations irrespective of location or etiology may interfere with the prognosis of endodontic treatment. This iatrogenic or mechanical or pathological communication between root canal system and external tooth surface should be sealed with a biocompatible materials as soon as possible¹². The present study evaluated the sealing ability of Resin modified Glass Ionomer Cement, MTA and Biodentine as furcation repair materials in mandibular molars using a dye penetration method. Dye penetration technique has long been used in endodontics because of its ease of performance and difficulty of other available techniques. Dye penetration methodology was employed in this study, which according to Camps J and Pashley gave similar results to the fluid-filtration technique as both are based on quantitative measurements of liquid passage within interfaces¹³. The use of a dye is regarded as the easiest and most cost-effective method for detecting micro-leakage.

Methylene Blue dye was used in our study because it easily allows quantitative measurement of the area of dye penetration by linear measurement methods.

Various techniques such as bacterial leakage, fluid filtration method radioisotopes, and dye penetration were used to measure the sealing ability of repairing materials.

In the present study, the dye penetration method was selected for the evaluation of the microleakage along the surface of the perforation cavity and the restorative material. In the literature various types of dyes have been used to evaluate material's sealing ability, including methylene blue, fuchsin, rhodamine B, silver nitrate, India ink and Pelikan ink. We did not select bacterial leakage models since MTA exerts antibacterial effects, nor we use the fluid transport mode since it cannot be performed reliably in perforation models.

Biodentine

As shown in the results of the present study, the newer introduced material Biodentine exhibited lowest microleakage because it is a Calcium silicate-based material that has polycarboxylate-based hydro-soluble polymer system described as water-reducing agent to reduce the overall water content of the mix, along with CaCl_2 as a setting accelerator. It bonds chemo-mechanically with the tooth along with the formation of tag like structures composed of Calcium or Phosphate rich crystalline deposits which increases over time hence minimizing the gap between tooth and Biodentine. Biodentine proves to be superior than MTA because Mineral Trioxide Aggregate has certain drawbacks such as difficult in handling, long setting time, and potential discoloration.

Compared to MTA, Biodentine handles easily and needs much less time for setting. Unlike other Portland cement-based products, it is sufficiently stable so that it can be used both for pulp protection and temporary fillings¹⁴. This is why the manufacturer recommends to fill the entire cavity completely with Biodentine in a first step and to reduce it to a base/dentine substitute level in a second visit one week to 6 months later before definitive restoration. For successful capping it is, however, important to seal the cavity against bacterial invasion in a one-stage procedure^{15,16}. While there is extensive evidence documenting that composite fillings are leak-proof, few pertinent data are available for Biodentine.

Clinical Applications

As stated by manufacture, Biodentine has many applications in Dentistry such as crown and root dentine repair treatment, repair of perforations or resorptions, apexification and root-end fillings. The material can also be used in class II fillings as a temporary enamel substitute and as permanent dentine substitute in large carious lesions. The manufacturer claimed about the biocompatibility and the bioactivity of the material, which is important when used as indirect and direct pulp capping and pulpotomy. Furthermore, it preserves pulp vitality and promotes its healing process.

Pérard et al.¹⁷ assessed the biological effects of Biodentine for use in pulp-capping treatment, on pseudo-odontoblastic (MDPC-23) and pulp (Od-21) cells. Secondly, the same authors evaluated the effects of Biodentine and MTA on gene expression in cultured spheroids. They concluded that Biodentine and MTA may modify the proliferation of pulp cell lines. Their effects may fluctuate over time, depending on the cell line considered. The observed similarity between Biodentine and MTA validates the indication for direct pulpcapping claimed by the manufacturers. Likewise, Nowicka et al.¹⁸ compared the response of the pulp-dentine complex in human teeth after direct capping Biodentine and MTA. They concluded that Biodentine had a similar efficacy in the clinical setting and may be considered an interesting alternative to MTA in pulp-capping treatment during vital pulp therapy.

Chemical Composition and Characteristics

According to the manufacturer, Biodentine consists of a powder in a capsule and liquid in a pipette. The powder mainly contains tricalcium and dicalcium silicate, the principal component of Portland cement, as well as calcium carbonate. Zirconium dioxide serves as contrast medium. The liquid consists of calcium chloride in aqueous solution with an admixture of polycarboxylate. Once mixed, Biodentine sets in approximately 12 minutes. The consistency of Biodentine is similar to that of phosphate cement¹⁹. Camilleri et al.²⁰ characterized and investigated the hydration of Biodentine and laboratory manufactured cement made with a mixture of tricalcium silicate and zirconium oxide and compared their properties to MTA Angelus. They reported that all the cement pastes tested were composed mainly of tricalcium silicate and a radiopacifier. The laboratory manufactured cement contained no other additives. Biodentine included calcium carbonate which together with the additives in the mixing liquid resulted in a material with enhanced chemical properties relative to TCS-20-Z prototype cement. On the other hand MTA Angelus displayed the presence of calcium, aluminum and silicon oxides in the un-hydrated powder. These phases are normally associated with the raw materials indicating that the clinker of MTA Angelus is incompletely sintered leading to a potential important variability

in its mineralogy depending on the sintering conditions. As a consequence, the amount of tricalcium silicate is less than in the two other cements leading to a slower reaction rate and more porous microstructure.

Biocompatibility and Cytotoxicity

The manufacturer stated that Biodentine considered as biocompatible material. Biodentine was shown to be biocompatible, i.e. it does not damage pulpal cells in vitro or in vivo, and is capable of stimulating tertiary dentin formation. Hard tissue formation is seen both after indirect and direct capping with Biodentine. Laurent et al. compared the biocompatibility of Biodentine with that of MTA and a hardening calcium hydroxide. They reported that Biodentine is biocompatible. This new material has no adverse effect on cell differentiation or specific cell functions. Shayegan et al. assessed and compared, in primary pig teeth, the pulp response after a pulpotomy using Biodentine, white MTA, or formocresol (FC) and repeat the same after direct pulp capping using Biodentine, white MTA, or calcium hydroxide. They concluded that Biodentine and white MTA are both suitable, biocompatible materials for pulp capping in primary teeth of pigs. Zhou et al. examined the effect of a Biodentine on the viability of human gingival fibroblasts. They reported that Biodentine caused gingival fibroblast reaction similar to that by MTA. Both materials were less cytotoxic than glass ionomer cement.

Bioactivity

The manufacturer stated that Biodentine considered as bioactive material. Goldberg described the bioactivity of this material, demonstrating the formation of apatite when immersed in phosphate solution. About et al. investigated Biodentine bioactivity by studying its effects on pulp progenitor cells activation, differentiation and dentine regeneration in human tooth cultures. They concluded that Biodentine is stimulating dentine regeneration by inducing odontoblast differentiation from pulp progenitor cells. Han and Okiji compared white MTA, EndoSequence BC sealer and Biodentine with regard to their ability to produce apatites and cause Ca and Si incorporation in adjacent human root canal dentine after immersion in phosphate-buffered saline (PBS). They concluded that Biodentine and white MTA, BC sealer showed less Ca ion release and did not show Ca and Si incorporation as deeply in human root canal dentine when immersed in PBS for up to 90 days.

Sealing Ability and Success

Biodentine is stronger mechanically, less soluble and produces tighter seals. This qualifies it for avoiding three major drawbacks of calcium hydroxide, i.e. material resorption, mechanical instability and the resultant failure of preventing microleakages.

Pradelle-Plasse et al. found that Biodentine causes alkaline corrosion on the hard tissue, which leads to a so-called “mineral interaction zone”. Due to remodelling processes, the sealing of the dentine by Biodentine improves in the course of time. They reported that Biodentine can deposit impermeably onto the cavity walls and prevents microleakage. About et al. studied effect of Biodentine on pulp progenitor cells activation, differentiation and dentine regeneration in human tooth cultures. Their study exhibited that Biodentine can stimulate dentine regeneration by inducing odontoblast differentiation from pulp progenitor cells. Han and Okiji compared calcium and silicon uptake by adjacent root canal dentine in the presence of phosphate buffered saline using Biodentine and MTA. The results showed that both materials formed a tag-like structure composed of the material itself or calcium- or phosphate rich crystalline deposits. The thickness of the Ca- and Si-rich layers increased over time, and the thickness of the Ca- and Si-rich layer was significantly larger in Biodentine compared to MTA after 30 and 90 days, concluding that the dentine element uptake was greater for Biodentine than for MTA.

Antibacterial Properties

Firla claimed that during the setting phase of Biodentine, calcium hydroxide ions are released from the cement. This results in a pH of about 12.5 and a basification of the surroundings. This high pH inhibits the growth of microorganisms and can disinfect the dentine.

Morphological and Chemical Characteristics of the Interface between Human Dentine and Biodentine
The morphological and chemical characteristics of the interface between human dentine and new calcium silicate based dental cement were investigated. The dentine Biodentine interface is dynamic and interactive; that is manifested by water movement between the two substrates, and hydrated cement diffusion into the dentine, accompanied by microstructural changes.

MTA

Mineral Trioxide Aggregate (MTA) was developed by Torabinejad and co-workers to fulfil the ideal criteria of a root perforation repair material. MTA is a type of hydraulic cement that requires water to set. In simple terms, hydraulic cements are finely ground materials (powders) that when mixed with water gradually or instantly set and harden in air or in water; the reaction resulting in the formation of hydrated compounds whose

strength increases with time. MTA consists of fine hydrophilic particles that on contact with water set to a hard composition through the creation of a colloidal gel.

Clinical Applications

MTA used increasingly in a wide range of clinical treatments. It was first developed and introduced in endodontics for the repair of root perforations. Subsequently, it has been widely used as a root-end filling material. It has also been used in vital pulp treatments, including direct pulp capping and pulpotomy of pulps in immature teeth as reported by Torabinejad and Chivian. In addition, as hard tissue induction is one of its exceptional properties, it has been suggested as an apical barrier in treatment of teeth with open apices and necrotic pulps. MTA also provides an effective seal against penetration of bacteria and their by-products and thus has been recommended as a temporary filling material and as a coronal plug after filling of the root canal system. Moreover, it is recommended for the non-surgical repair of invasive cervical root resorption. Yildirim and Gencoglu reported new hard tissue formation in two horizontal root fracture lines after a 5-year follow-up and suggested the use of MTA in the treatment of such cases. In addition, Gomes-Filho et al. reported that a sealer based on MTA stimulated mineralization and thus advocated its use as a root canal sealer. The use of MTA has also been suggested in regenerative endodontics for treatment of immature permanent teeth with periapical disease.

Chemical Composition and Characteristics

MTA is a powder, which consists of fine hydrophilic particles of tricalcium silicate, tricalcium aluminate, tricalcium oxide, silicon oxide. When MTA is mixed with water, it becomes a colloidal gel. Setting time of MTA is approximately 3-4 hours. During the initial stages the pH is 10.2 and later when the material has set, it becomes 12.5. Camilleri et al. showed through x-ray diffraction analysis, the components of MTA to be tricalcium silicates and aluminates with bismuth oxide. They also showed that the material was crystalline in structure. It was found that blood contamination affected the retention characteristics of MTA. In a study conducted by Camilleri, it was seen that unreacted MTA was composed of impure tri-calcium and di-calcium silicate and bismuth oxide and traces of aluminate.

Biocompatibility and Cytotoxicity

Torabinejad et al.²¹ compared bone tissue reaction to implanted MTA and Super EBA in guinea pigs and reported that MTA was considered as biocompatible materials. Koulaouzidou et al. investigated the cytotoxicity of 2 brand of MTA and compared with Super EBA and Vitrebond. They found that both MTA materials caused the least cytotoxic effect and could be regarded as biologically inert materials.

Bioactivity

MTA is considered as a bioactive material with possible osteoinductive properties. Bonson et al. exposed cell cultures of gingival and periodontal ligament fibroblasts to various root-end filling materials including MTA and indicated that only MTA was capable of modifying differentiation of both fibroblast populations, resulting in significantly increased levels of alkaline phosphatase activity. Activity of alkaline phosphatase is regarded as an indicator of bone formation. Moreover, the potential property of MTA to promote differentiation of dentinoblasts from clonogenic cells of the dental pulp has been demonstrated by Zhao et al.

Antibacterial Activity of MTA

Some of the major advantages of MTA, such as antibacterial activity and conduction of hard tissue, can be best rationalised as a result of its alkalinity. In a laboratory study Torabinejad et al. measured the pH value of the initial prototype of MTA and reported that its pH when freshly mixed MTA was 10.2, which rose to 12.5 after 3 h. Chng et al. demonstrated that the pH value of tooth coloured MTA rose to 13.0 at 60 minutes after mixing, which was attributed to the continuous formation of calcium hydroxide during the hydration process²². The pH value of tooth coloured MTA was reported to be higher than grey MTA.

Sealing Ability

Nakata et al. evaluated the ability of MTA and amalgam to seal furcal perforations in extracted human molars using an anaerobic bacterial leakage model. *Fusobacterium nucleatum* was used in this study and it was concluded that MTA was significantly better than amalgam at preventing leakage. Roy et al. also observed that an acidic environment did not alter the sealing ability of MTA. Fogel and Peikoff observed that MTA was better than amalgam, IRM, a dentine-bonded resin and super-EBA in preventing microleakage. All these studies prove that MTA is equivalent or superior in its sealing ability compared to contemporary root-end filling materials. Several investigations were completed to determine the sealing properties of MTA. Gray and white ProRoot MTA performed equally well in sealing furcal perforations. There is no significant difference between the gray

and white ProRoot MTA in sealing furcal perforations of extracted human molars. There was found no significant difference in saliva leakage between gray and white MTA when it was used as an orthograde root canal filling material as stated by Al-Hezaimi et al.

Resin modified GIC

This study use GC Fuji LC for furcation perforation repair because is a resin-modified light-cured glass ionomer cement, which have been found to exhibit an expansion after setting, possibly increasing the sealing ability of the material^{23,24}. As this product is light-cured within 20 seconds, one may assume that it will not dramatically be affected by the moisture of the periodontal tissues. According to the manufacturer, RMGIC has improved mechanical properties. It adheres chemically to dentin in the presence of moisture, without the need for conditioning, and exhibits greater tensile bond strength than traditional glass ionomers. Unlike powder/liquid liners which can be fiddly and time-consuming to use, this Pak dispenser is quick and precise. Mixing time to the ideal consistency it takes only 10 seconds and unlike mixing powder/liquid material, the final product is free of air bubbles. After the mixing procedure, the cement inserted in the perforation cavities and was light-cured for 20 seconds. However, our results showed a high microleakage suggesting a false polymerization possibly due to the presence of moisture, despite the fact that we have used a dual-cured cement. The light cannot be transmitted effectively in the perforation defect and due to the presence of moisture the polymerization cannot be achieved effectively.

Resin modified Glass Ionomer cement can be used as a dentin substitute that has the ability to exhibit chemical bond to tooth structure but the marginal seal is compromised because of its dissolution in tissue fluids and it's being technique sensitivity²⁵. A higher percentage of dye penetration in GIC may be due to the polymerization contraction of the material²⁶. Contamination of the dentinal surface with excessive moisture, solvent or presence of voids could affect bonding, making it unpredictable under clinical conditions.

VI. Conclusion

On comparative evaluation of results of this in vitro study, it was concluded that RMGIC, MTA & Biodentine exhibited microleakage with Biodentine showing the least microleakage of all. This study was a humble effort to evaluate the sealing ability of the newly introduced material Biodentine. However, it is still open for further research not only for the sealing ability but also the related physical properties as well as critical manipulative steps.

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