American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN: 2320-0936
Volume-14, Issue-11, pp-11-15
www.ajer.org
Research Paper Open Access

In Vitro Fracture Resistance of Teeth Treated with Simulated Endodontic Revascularization Using MTA® White or BIODENTINE™ As a Lining Material

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ABSTRACT : *Immature teeth with an open apex may present vertical fracture during endodontic treatment or secondary to dental trauma. Revascularization/revitalization is a regenerative procedure that uses bioceramic materials and aims at closing the apex and thickening the root.*
Objective*: To compare the in vitro fracture resistance of immature teeth treated with simulated revascularization using MTA® Ángelus® White (Ángelus, Lodrina, Paraná Brasil) or Biodentine™ (Septodont, Saint-Maur-des-Fossés, France) as barriers, and coronal reconstruction with resin Te-econom Plus (IvoclarVivadent).*
Materials and methods*: 15 single-rooted premolars with simulated immature apex were used, which was filled with human blood, obtaining a blood clot. MTA® white (Group 1, n=7) or Biodentine™ (Group 2, n=7) plus resin reconstruction were placed on the clot 3-4 mm below the cement enamel junction. One tooth (Group 3) with immature apex that was only reconstructed with resin served as a control. The samples were loaded at 135° by a 6 mm diameter stainless steel attachment in a universal testing machine at a crosshead speed of 1 mm/min until fracture was achieved. The data were recorded in Newtons using one-way ANOVA and Scheffe's post hoc at an alpha .05.*
Results*: Statistically significant differences were identified between groups (p<.05). The MTA white group presented greater fracture resistance than control group.*
Conclusions*: The use of bioceramic material such as MTA white provides greater in vitro fracture resistance of immature teeth treated with simulated endodontic revascularization.*
KEYWORDS: *Revascularization, Biodentine, MTA*

Date of Submission: 01-11-2025 Date of acceptance: 08-11-2025

I. INTRODUCTION

Dental trauma is most common in school-aged children and young adults [1]. Extraction of traumatized immature teeth is frequent, even though alternative treatments exist that can preserve the teeth [2]. Immature teeth with pulpal and periapical pathologies caused by caries or trauma are characterized by open apices and thin root walls, making them susceptible to crown-root fracture [3]. In these cases, regenerative endodontics is the treatment of choice. Its objective is to close the apex and thicken the root walls to withstand the functional loads of mastication and reduce the likelihood of root fracture [4-6]. This regenerative procedure increases the success rate of endodontic treatments such as revascularization/revitalization of immature teeth, with reported success rates ranging from 60% [4] to over 90% [7].

Several procedures utilize autologous regenerative elements within the root canal, such as platelet-rich plasma (PRP), platelet-rich fibrin (PRF), or autologous fibrin matrix [8]. However, one of the most common revascularization methods is clot induction [9]. This method involves disinfecting the root canal and then irritating the periapical tissues to induce bleeding and clot formation within the canal [9,10]. The induced clot acts as a

fibrin-based scaffold [11] where mesenchymal stem cells can release growth factors. These growth factors can differentiate into various cell types, including odontoblasts, chondrocytes, and myocytes, leading to the formation of specialized tissues [12].

However, the formed clot must be protected by a barrier to prevent bacterial infiltration and contamination of the clot and surrounding tissue, as this contamination could lead to the failure of the regenerative treatment. The most commonly used biomaterials placed over the clot are calcium silicate-based, such as ProRoot Mineral Aggregate Trioxide (MTA) (Dentsply Sirona, York, PA, USA); Angelus® White MTA (Angelus, Lodrina, Paraná, Brazil), which has demonstrated remineralizing capacity [13,14]; or Biodentine (Septodont, Saint-Maur-des-Fossés, France), which also possesses excellent biocompatibility [15,16] and micromechanical retention to the dentin of the root canal walls [17].

These biomaterials should be 3–4 mm thick [18] and placed below the cementoenamel junction to prevent bacterial microleakage and unwanted coronal discoloration that could affect tooth aesthetics. A 4 mm barrier has been reported and suggested to improve sealing and root reinforcement [18]. However, the role of the biomaterials coating the clot in the fracture resistance of teeth undergoing endodontic revascularization is unclear. In these cases of teeth with immature apices, high fracture resistance is desirable in teeth undergoing this type of regenerative procedure to reduce the likelihood of root fracture and promote success and longevity of the tooth. The aim of this study was to compare the in vitro fracture resistance of immature teeth treated with sham revascularization using MTA® Angelus® White or Biodentine™ as barriers, plus coronal restoration with resin.

II. MATERIALS AND METHODS

The in vitro experimental study was conducted using 15 single-rooted premolars recently extracted for orthodontic or periodontal reasons. The teeth were standardized to 17 mm in length by transversely sectioning a coronal and apical portion of the teeth. The sample was randomly assigned to three groups: Group 1: seven teeth treated with MTA® Angelus® White overlay over the clot and Te-econom Plus resin as a coronal restoration. Group 2: seven teeth treated with Biodentine™ overlay over the clot and Te-econom Plus resin as a coronal restoration. Group 3 (Control): one tooth with a simulated immature apex, without overlay treatment, restored only with Te-econom Plus resin as a coronal restoration.

Simulation of an immature apex

To simulate an immature apex characteristic of young teeth, the root canals were instrumented with the Protaper Gold System (Dentsply Dental, Tulsa, OK, USA) to size F5 and subsequently enlarged at the apical foramen with Peeso burs (Mani, Inc. Tochigi, Japan) (No. 1-4) to achieve an apical opening of 1.10 mm. For root canal disinfection, final irrigation was performed with 17% Zeyco® EDTA (Viarden Zapopan, Jalisco, Mexico) for 1 minute and 5.25% sodium hypochlorite, Viarzoni-T (Viarden Zapopan, Jalisco, Mexico). The root canal was then dried with #80 paper points.

Simulation of the periodontal ligament and blood clot

The tooth roots were immersed in KemDent 225g all-season pink wax to simulate 0.2 mm of the periodontal ligament and were subsequently mounted on temporary acrylic resin blocks (Bisacryl Nic Tone MDC® dental) measuring 25 x 10 mm (height x width). Fifteen milliliters of blood were drawn from a donor, and using a BD Ultrafine 29 x 13 insulin syringe, 0.5 ml of this blood was injected into the root canals, filling them 2 to 3 mm below the cementoenamel junction until a blood clot formed. After 15 minutes, 3-4 mm of MTA Angelus® White (Angelus, Lodrina, Paraná, Brazil) or Biodentine™ (Septodont, Saint-Maur-des-Fossés, France) were placed over the clot, depending on the assigned group. Figure 1. The control was a tooth with a simulated immature apex, which did not receive a capping treatment and was only restored with Te-econom Plus resin as a coronal reconstruction.

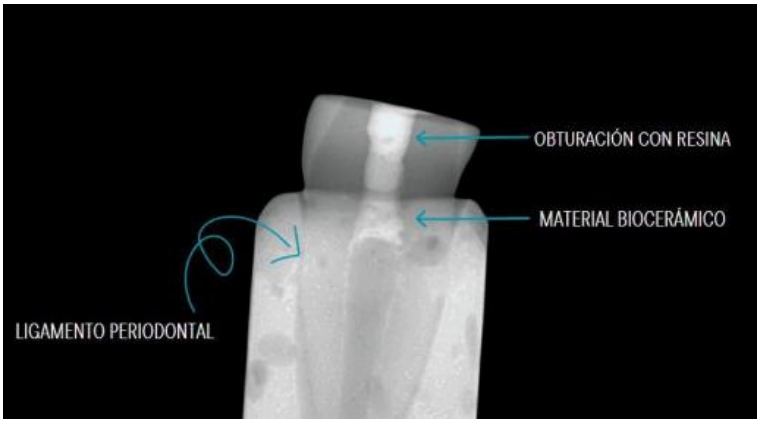

Figure 1. Radiographic verification of the placement of 3 mm of material.

Fracture resistance test

Once the veneering materials were placed, the teeth were restored with Te-econom Plus resin (Ivoclar Vivadent). Each sample was placed in a base and subjected to a compressive load in a Universal Testing Machine (Alliance RT/30 MTS®) at a crosshead speed of 1 mm/min, applied by a flat attachment with a diameter of 6 mm. The load was applied to the cingulum at an angle of 135° until fracture occurred. The values measured at the time of fracture were recorded in Newtons. The data were analyzed with one-way ANOVA and Scheffé post hoc test, using an alpha value in SPSS 23.0 (IBM® SPSS® Statistics).

III. RESULTS

The results are presented in Table 1. One-way ANOVA revealed significant differences between the groups (p=0.007), with Scheffe's test indicating that MTA® Angelus® White exhibits significantly greater fracture resistance than the control group (p=0.013). Table 2.

Table 1. Descriptive statistics (Nw) of fracture resistance in the study groups.

Group	Values		N	*p Value*
CONTROL	Mean		215.6	
	Standar deviation		0.00	
MTA	Mean		547.45	
	95% CI	Lower limit	424.29	
		Upper limit	670.61	
	Standar deviation		133.17	
	Minimum		405.00	*0.007*
	Maximum		769.00	
BIODENTINE	Mean		379.84	
	95% CI	Lower limit	295.74	
		Upper limit	463.93	
	Standar deviation		90.93	
	Minimum		243.00	
	Maximum		477.00	

Table 2. Comparative analysis with the Scheffe test of fracture resistance between the different study groups.

Multiple comparisons		p Value
CONTROL	MTA	0.013*
	BIODENTINE	0.253
BIODENTINE	MTA	0.068

IV. DISCUSSION

In this study, single-rooted premolars with simulated immature apices were used under in vitro conditions to compare two bioceramic materials: MTA® Angelus® White and Biodentine™. According to the manufacturer of MTA® Angelus® White, this material exhibits calcium ion release, low solubility, a compressive strength of 44.2 MPa, biocompatibility, cementum neoformation capacity, and dentin remineralization. The manufacturers of Biodentine™, on the other hand, indicate that it possesses bioactivity, biocompatibility, sealing capacity, mechanical properties similar to those of dentin, an alkaline pH, and anti-inflammatory properties. In this study, simulations of immature apices were performed using Peeso burs to obtain an apical opening diameter of 1.10 mm, following protocols established in previous research [19,20]. Although this method has been used previously for simulating immature teeth, it has limitations, as this simulation resembles the shape of immature teeth but not the structural and physiological properties [5,6] of immature teeth in the patient's mouth, since endodontic revascularization is a procedure that does not occur under in vitro conditions. In fracture resistance tests, the location of the fracture plays an important role in deciding whether a tooth should be extracted or can be restored. In our study, cervical fractures were observed, and three of these were considered restorable. Therefore, it can be observed that most of the samples resulted in fractures of teeth that could not be restored. The results observed in this study with white MTA establish that fracture resistance is greater than in the control group that did not receive biomaterial over the clot. It appears that the placement of MTA improves fracture resistance in teeth with immature apices. However, our results contrast with those obtained by Elnaghy AM and Elsaka SE [20], who did not report statistically significant differences in fracture resistance in root canal obturations with MTA or Biodentine, although this study did not use endodontic revascularization. Regardless of the procedural differences between our study and that of Elnaghy AM and Elsaka SE, we believe that the differences may be due to the fact that these authors widened the root apex to 1.7 mm, thereby achieving greater weakening of the root structure. Therefore, it should be considered that cases with immature apices present varied dimensions that can lead to different fracture resistance, given that each case may be different. Guven et al. [21], in simulated immature teeth with an apical diameter of 1.7 mm, obturated root canals with BioAggregate, MTA Angelus, MTA Plus, or EndoSequence Root Repair Material, storing the samples for two years before performing a fracture resistance test. They reported that white MTA exhibited the lowest fracture resistance. This study highlights the importance of the effect of time on the preservation of the physical and mechanical properties of biomaterials. Conversely, the hypothesis that biomaterials placed inside the root canal promote greater fracture resistance is supported by the results reported by Karapinar M et al [22], who, in immature root canals with an apical diameter of 2.1 mm, obturated the canals with white MTA or Biodentine, or BisFil 2B flowable CR or BisFil II posterior CR resins, finding root reinforcement by obtaining fracture resistance values similar to those found in intact teeth. Although these last two studies did not use the biomaterials as coatings over a clot in cases of simulated revascularization, they do provide information on the effect they can have in teeth with simulated immature apices. In our study, we did not observe statistically significant differences in fracture resistance between MTA and Biodentine. Although Biodentine has been reported to have higher compressive strength values than MTA in compressive strength tests, with this compressive strength increasing with Biodentine from day 1 to day 28 [23]. As can be seen in the heterogeneity of studies, further research is needed on the fracture resistance of teeth with immature apices and simulated revascularization in order to generate knowledge that will allow us to identify which materials could offer advantages in fracture resistance in this type of tooth, aiming for clinical longevity in these cases.

V. CONCLUSION

Under the limitations and conditions of the in vitro study, the following conclusions were drawn. The in vitro fracture resistance of immature teeth treated with simulated revascularization was greater when using MTA® Angelus® White as a coating over the clot. The fracture resistance of a premolar with a simulated immature apex that does not receive a ceramic biomaterial is significantly lower than when a bioceramic restorative material is used. It is possible that a 3- to 4-mm coating of a calcium silicate-based biomaterial such as MTA® Angelus® White or Biodentine™ over the clot in teeth with an immature apex promotes greater fracture resistance.

REFERENCES

[1]. Levin L, Day PF, Hicks L, O'Connell A, Fouad AF, Bourguignon C, Abbott PV. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: General introduction. *Dent Traumatol*. 2020 Aug;36(4):309-313.

[2]. Murray PE, Garcia-Godoy F, Hargreaves KM. Regenerative endodontics: a review of current status and a call for action. *J Endod.* 2007 Apr;33(4):377-90.

[3]. Lawley GR, Schindler WG, Walker WA 3rd, Kolodrubetz D. Evaluation of ultrasonically placed MTA and fracture resistance with intracanal composite resin in a model of apexification. *J Endod*. 2004 Mar;30(3):167-72.

[4]. Wikström A, Brundin M, Romani Vestman N, Rakhimova O, Tsilingaridis G. Endodontic pulp revitalization in traumatized necrotic immature permanent incisors: Early failures and long-term outcomes-A longitudinal cohort study. *Int Endod J*. 2022 Jun;55(6):630-645.

[5]. Torabinejad M, Nosrat A, Verma P, Udochukwu O. Regenerative Endodontic Treatment or Mineral Trioxide Aggregate Apical Plug in Teeth with Necrotic Pulps and Open Apices: A Systematic Review and Meta-analysis. *J Endod.* 2017 Nov;43(11):1806-1820.

[6]. Pereira AC, Oliveira ML, Cerqueira-Neto ACCL, Vargas-Neto J, Nagata JY, Gomes BPFA, Ferraz CCR, de Almeida JFA, de-Jesus-Soares A. Outcomes of traumatised immature teeth treated with apexification or regenerative endodontic procedure: a retrospective study. *Aust Endod J*. 2021 Aug;47(2):178-187.

[7]. Meschi N, Palma PJ, Cabanillas-Balsera D. Effectiveness of revitalization in treating apical periodontitis: A systematic review and meta-analysis. *Int Endod J*. 2023 Oct;56 Suppl 3:510-532.

[8]. *A.A.O. Endodontists*, Regenerative endodontists. https://www.aae. org/specialty/clinical-resources/regenerative-endodontics/#.

[9]. Jeeruphan T, Jantarat J, Yanpiset K, Suwannapan L, Khewsawai P, Hargreaves KM. Mahidol study 1: comparison of radiographic and survival outcomes of immature teeth treated with either regenerative endodontic or apexification methods: a retrospective study. *J Endod.* 2012 Oct;38(10):1330-6.

[10]. Xuan K, Li B, Guo H, Sun W, Kou X, He X, Zhang Y, Sun J, Liu A, Liao L, Liu S, Liu W, Hu C, Shi S, Jin Y. Deciduous autologous tooth stem cells regenerate dental pulp after implantation into injured teeth. *Sci Transl Med*. 2018 Aug 22;10(455):3227.

[11]. Chen YJ, Zhao YH, Zhao YJ, Liu NX, Lv X, Li Q, Chen FM, Zhang M. Potential dental pulp revascularization and odonto-/osteogenic capacity of a novel transplant combined with dental pulp stem cells and platelet-rich fibrin. *Cell Tissue Res*. 2015 Aug;361(2):439-55.

[12]. Orti V, Collart-Dutilleul PY, Piglionico S, Pall O, Cuisinier F, Panayotov I. Pulp Regeneration Concepts for Nonvital Teeth: From Tissue Engineering to Clinical Approaches. *Tissue Eng Part B Rev*. 2018 Dec;24(6):419-442.

[13]. Zhu C, Ju B, Ni R. Clinical outcome of direct pulp capping with MTA or calcium hydroxide: a systematic review and meta-analysis. *Int J Clin Exp Med*. 2015 Oct 15;8(10):17055-60.

[14]. Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I. Physicochemical basis of the biologic properties of mineral trioxide aggregate. *J Endod*. 2005 Feb;31(2):97-100.

[15]. *American Association of Endodontists*. Considerations for Regenerative Procedures. https://www.aae.org/specialty/wp-content/uploads/sites/2/ 2021/08/ClinicalConsiderationsApprovedByREC062921.pdf. Accessed 26 May 2023.

[16]. da Fonseca TS, da Silva GF, Tanomaru-Filho M, Sasso-Cerri E, Guerreiro-Tanomaru JM, Cerri PS. In vivo evaluation of the inflammatory response and IL-6 immunoexpression promoted by Biodentine and MTA Angelus. *Int Endod J*. 2016 Feb;49(2):145-53.

[17]. Mousavi, S.A.; Khademi, A.; Soltani, P.; Shahnaseri, S.; Poorghorban, M. Comparison of sealing ability of ProRoot mineral trioxide aggregate, biodentine, and ortho mineral trioxide aggregate for canal obturation by the fluid infiltration technique. *Dent. Res. J*. 2018, 15, 307–312.

[18]. Gunal E, Bezgin T, Ocak M, Bilecenoglu B. Effects of various thicknesses and levels of mineral trioxide aggregate coronal plugs on nanoleakage and fracture resistance in revascularization: An in vitro study. *Aust Endod J*. 2021 Dec;47(3):608-615.

[19]. Mello I, Michaud PL, Butt Z. Fracture Resistance of Immature Teeth Submitted to Different Endodontic Procedures and Restorative Protocols. *J Endod*. 2020 Oct;46(10):1465-1469.

[20]. Elnaghy AM, Elsaka SE. Fracture resistance of simulated immature teeth filled with Biodentine and white mineral trioxide aggregate - an in vitro study. *Dent Traumatol*. 2016 Apr;32(2):116-20.

[21]. Guven Y, Tuna EB, Dincol ME, Ozel E, Yilmaz B, Aktoren O. Long-Term Fracture Resistance of Simulated Immature Teeth Filled with Various Calcium Silicate-Based Materials. *Biomed Res Int*. 2016; 2016:2863817.

[22]. Karapinar-Kazandag M, Basrani B, Tom-Kun Yamagishi V, Azarpazhooh A, Friedman S. Fracture resistance of simulated immature tooth roots reinforced with MTA or restorative materials. *Dent Traumatol.* 2016 Apr;32(2):146-52. doi: 10.1111/edt.12230. Epub 2015 Sep 28. PMID: 26411925.

[23]. Butt N, Talwar S, Chaudhry S, Nawal RR, Yadav S, Bali A. Comparison of physical and mechanical properties of mineral trioxide aggregate and Biodentine. *Indian J Dent Res*. 2014 Nov-Dec;25(6):692-7.