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Comparative Evaluation of Push-Out Bond Strength of Bioactive Bioceramic MTA and Conventional MTA in Simulated Apexification: An in-Vitro Study

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Abstract

Aim: To evaluate and compare the push-out bond strength of Conventional MTA and Bioactive Bio-ceramic MTA in simulated apexification.

Materials and Methods: Twenty freshly extracted human single rooted mandibular premolar teeth for each study (n=10 each group) with completely formed apices and straight canals were selected. Apical 3mm root resection was done to simulate open apex. A 2mm thickness slice of the root of each tooth was cut perpendicular to the long axis of the root. The canals of all the 2mm dentin sections were enlarged to a standardized cavity size of 1.3 mm in diameter. **Group 1:** ANGELUS MTA (White). **Group 2:** Bioactive Bio-ceramic MTA Neo PUTTY MTA (Nu Smile, Houston, TX, USA). The Push-Out bond strength testing was done using Universal testing machine (Instron India Pvt., Ltd.)

Statistical analysis: Independent Samples t parametric test, SPSS for Windows (Statistical Presentation System Software, SPSS Inc.) version 17.0.

Results: Bioactive bio-ceramic Neoputty MTA showed statistically significant lower microleakage values and higher bonding values when compared to Conventional MTA ($p<0.05$).

Conclusion: The Bioactive Bio-ceramic Neoputty MTA had better bonding ability than The Conventional MTA.

Keywords: Mineral trioxide aggregate (MTA), Bioactive Bio-ceramic, Apical Microleakge, Apexification

Introduction

The root apex of a non-vital young permanent tooth is incomplete and the dentinal walls are thin, which makes them susceptible to fracture. Apexification is the method of inducing apical closure through the formation of mineralized tissue in the apical pulp region of a non-vital tooth with an incompletely formed root (open apex).[1] It is a procedure indicated for non-vital immature teeth that require root canal treatment.

Traditionally, calcium hydroxide Calcium hydroxide was one of the most widely used materials for apexification. Calcium hydroxide induces apical closure through the formation of mineralized tissue composed of osteocementum, osteodentin or bone, or by some combination of the three. [2]

Although calcium hydroxide induced apexification procedure is well accepted, certain drawbacks in the material have caused its usage to fall out of favor. The formation of the apical barrier can take several months, which require multiple visits, material must be changed periodically leading to issues with patient compliance. The tooth may be weakened by prolonged exposure to Calcium hydroxide decreasing intrinsic properties of exposed dentin. [3,4,5] There is increased possibility of tooth fracture during or after treatment. The nature of barrier might be porous or sometimes contain soft tissues. [6]

Recently, new Calcium silicate based materials have been introduced such as bio-ceramics. Bio-ceramics are bio inert, bioactive, and biodegradable, soluble or resorbable and are durable in tissues and can undergo beneficial interactions with surrounding tissues. [7]

Mineral trioxide aggregate (MTA) is a Calcium silicate based biocompatible material developed by Torabinejad in 1999. It has gained wide spread popularity for the apexification procedure as it provides apical hard tissue formation with significantly greater consistency than calcium hydroxide. Although, MTA is a material that has been proven biocompatible, it suffers certain clinical disadvantages including its handling properties and lengthy setting time. [8]

Premixed tri-calcium silicate-based putties, were introduced in 2010 to overcome these limitations of MTA. A new premixed bioactive bio-ceramic MTA (NeoPutty) material consist of an extremely fine, inorganic powder of tri-calcium/di-calcium silicate in a water-free organic liquid [Figure.1]. The product is packaged ready-to-use. No mixing is required. When applied, the water from the apical tissues, dentinal tubules or pulp causes the product to set. It is designed to set in vivo in the presence of moisture from the surrounding tissues. It has outstanding properties such as excellent biocompatibility, high radiopacity, non-staining. It releases calcium and hydroxide ions from the surface, promoting the formation of hydroxyapatite to ensure bioactive sealing. It is resin-free for maximum MTA concentration and maximum bioactivity. It delivers a ready-to-use material for immediate placement with zero waste, saving cost and chair time.

Marginal adaptation and bond strength of root-end filling materials are crucial factors for endodontic success because most endodontic failures arise from leakage at the root-end. [9]

The present study was conducted to evaluate and compare the Push-out bond strength of Bioactive Bio-ceramic MTA (NeoPutty) with Conventional Mineral Trioxide Aggregate (MTA).

Material and Methods

The study was approved by the Institutional Ethical Committee of PMS College of Dental Science and Research, Trivandrum, Kerala, India (PMS/IEC/2020-21/08).

Push-Out Bond Strength Evaluation

Twenty freshly extracted human single rooted mandibular premolar teeth (n =10 each group) with completely formed apices and straight canals were stored in normal saline until use. The teeth were cleaned with an ultrasonic scaler. A 3 mm section was removed from the apical portion of the root perpendicular to the long axis of root with a water-cooled low-speed diamond saw (Isomet; Buehler, Lake Bluff, NY, USA) [Figure.2]. Again a 2mm thickness slice of the remaining root of each tooth was cut with a water-cooled low-speed diamond saw (Isomet; Buehler, Lake Bluff, NY, USA) perpendicular to the long axis of the root [Figure.3,4] .The canals of all the 2mm dentin sections were enlarged to a standardized cavity size of 1.3 mm in diameter using SF 31 straight bur (head diameter 1.3mm) and No. 5 Gates-Glidden drills [Figure.5,6]. Each bur and Gates-Glidden drill was replaced after every 5 preparations. All sections were immersed in 17% EDTA solution for 3 min to remove the smear layer, followed by immersion in 1.5% sodium hypochlorite solution for 3 min. Sections were rinsed thoroughly with distilled water and dried using gauze pieces.

After instrumentation, the samples were divided into two groups:

Group 1: Mineral trioxide aggregate -ANGELUS MTA (White). The cavities of dentin sections were filled with Conventional MTA. Conventional MTA was mixed with sterile water and was carried into the cavity with the help of an angelus Messing's gun.

Group 2: Bioactive Bio-ceramic MTA Neo PUTTY MTA (NuSmile, Houston, TX, USA). The desired amount of Bioactive Bio-ceramic MTA (Neoputty) material available in the premixed syringe, were dispensed into a glass slab and was placed into the cavities with a Messing's gun. [Figure.7]

After this, the specimens were wrapped in a wet gauze piece and stored in an incubator at 37 ° C for 72 h.

Push-Out Bond Strength Testing

The Push-Out bond strength testing was done using Universal testing machine (Instron India Pvt., Ltd.) [Figure.8]. A stainless steel indenter of 1 mm in diameter was used to apply a compressive load with downward pressure on the surface of the tested material at a speed of 1 mm/min [Figure.9]. Samples were placed on a custom-made metal base with a hole in the center. The hole was aligned with the center of the test specimen. The indenter was aligned with the center of the test material so that it had 0.2 mm of clearance from the dentin wall. This allowed the stainless steel indenter of the testing machine to pass through freely once the bond between the test material and the root dentin wall was broken [Figure.10].

The maximum load at which the specimen was dislodged was recorded in Newtons (N).

The bond strength was calculated in MPa using the following formula:

$$\text{bond strength}\,(\text{MPa}) = \frac{\text{debonding force}\,(\text{N})}{\text{surface area}\,(\text{mm}^2)}.$$

MPa = N/2 πrh

Where **N** = the maximum load for each specimen, **r** = root canal radius in mm, **h** = the thickness of the root dentin disc in millimeters and **π** =3.14

Statistical Analysis

For all statistical evaluation, a two – tailed probability of value of < 0.05 was considered significant. For comparison between the groups, Independent Samples t Test was used. Statistical analysis was performed using SPSS for Windows (Statistical Presentation System Software, SPSS Inc.) version 17.0.

Results

Table 1 shows the maximum load scores of Conventional MTA and Bioactive Bio-ceramic MTA in Newtons [N].

Graph 1 shows that the maximum load required to displace specimens of Bioactive Bio-ceramic MTA was higher than that required for Conventional MTA specimens.

Table 2 shows the bond strength scores of Conventional MTA and Bioactive Bio-ceramic MTA in MPa.

Graph 2 shows that the bond strength values of Bioactive Bio-ceramic MTA are significantly higher than that of Conventional MTA.

Graph 3 shows the mean bond strength of Bioactive Bio-ceramic MTA and Conventional MTA.

Discussion

Failure of the root canal treatment may be attributed to a number of factors. The bond strength of root-end filling materials to root canal walls is an important factor because it is beneficial in maintaining the integrity of the cement-dentin interface. [10] Push-out bond strength testing is an efficient, practical and reliable method to evaluate the adaptation of a material to its surrounding root dentin. [11] The push-out test is used to measure the interfacial shear strength developed between different surfaces. It provides information about the adhesiveness of the tested material to the surface. [12] In push-out strength test, there is uniform stress distribution at the dentin-cement interface. [13]

The results of our study showed that Bioactive Bio-ceramic material had higher mean bond strength value of 20.62MPa compared to MTA with mean value of 9.26MPa, and hence the push-out bond strength scores between the two materials were statistically significant. Similar results was obtained by Iptek et al [14] in 2022 who compared the push-out bond strength between the bioactive bio-ceramic material NeoPutty and MTA Repair HP and concluded that the bioactive bio-ceramic material has the highest push-out bond strength values. Being active biomaterials, calcium silicate-based cements produce calcium phosphate and apatite-like precipitates at the cement-dentin interface and within the dentinal tubules. This results in the formation of tag-like structures and an interfacial hybrid layer that is responsible for chemical and mechanical bonding.[15] The bio-mineralization ability of calcium silicate-based cements is directly proportional to the amount of Ca^{2+} released by them and the presence of phosphate in the tissue fluids.[16] The higher bond strength values of the Bioactive Bio-ceramic material observed in the present study could be attributed to its higher content of calcium-releasing products triggering the formation of tag-like structures at the cement-dentin interface, resulting in increased resistance to dislodgement forces when compared to MTA.

Ree et al Schwartz et al [17] Wang et al in 2015, Juez el al [18] in 2019 had said about the benefits of using bio-ceramic in a premixed form and have found that mixing and handling characteristics of powder/liquid systems are very technique sensitive. Premixed bio-ceramic materials require moisture from the surrounding tissues to set. The premixed sealer, paste, and putty have the advantage of uniform consistency and lack of wastage. These properties provide improved performance to premixed Bio-ceramic when compared to MTA.

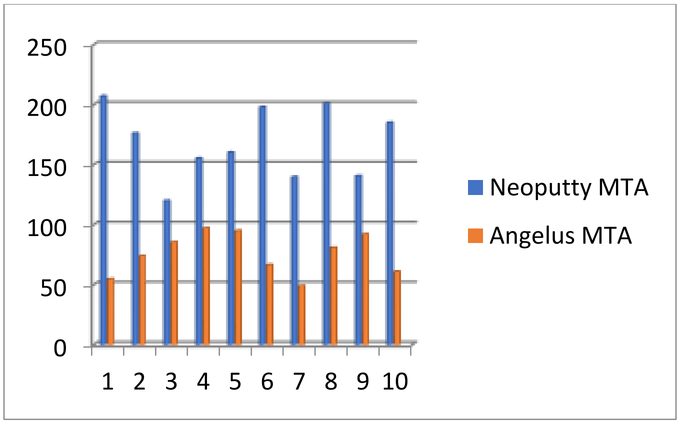
The statistically significant difference between microleakage and push-out bond strength values of Bioactive bio-ceramic material Neoputty may be attributed to its superior marginal sealing ability resulting from its hydrophilic properties, formation of an interfacial layer between the material and dentin and the formation of tag-like structures at the cement-dentin interface, resulting in increased resistance to dislodgement forces. The interfacial hybrid layer and the tag-like structures reduced the risk of marginal percolation and provided improved chemical and mechanical bonding.

Figures & Tables

Table 1: **Maximum load** between ANGELUS MTA & NEOPUTTY MTA in Newtons [N]

Tooth Samples	Angelus MTA Maximum load in Newtons [N] Group 1 (n = 10)	Neoputty MTA Maximum load in Newtons [N] Group 2 (n = 10)
1	54.721	207.129
2	74.060	176.013
3	85.525	119.809
4	97.025	155.432
5	95.036	160.234
6	66.421	198.135
7	48.935	139.873
8	81.052	201.094
9	92.061	140.768
10	60.873	185.261

Graph 1: The maximum load at which the specimens were dislodged



The bond strength was calculated in MPa using the following formula:

$$\text{bond strength}\left(\text{MPa}\right)=\frac{\text{debonding force}\left(\text{N}\right)}{\text{surface area}\left(\text{mm}^2\right)}.$$

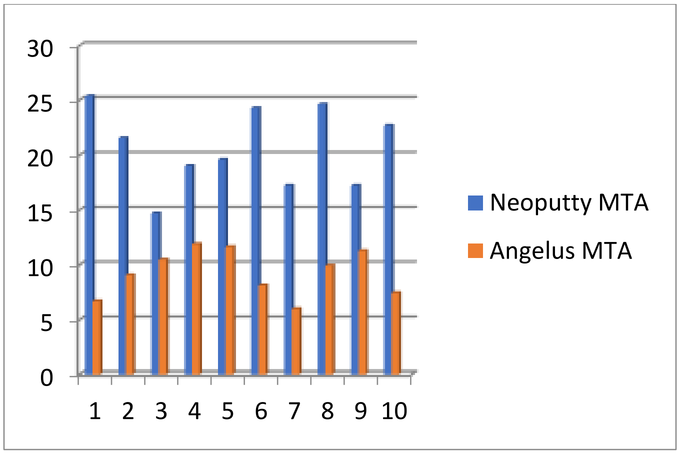
MPa = N/2 πrh

Where **N** = the maximum load for each specimen, r = root canal radius in mm, **h** = the thickness of the root dentin disc in millimeters and π =3.14

Table 2: **Bond strength** between ANGELUS MTA & NEOPUTTY MTA in **Mpa**

Tooth Samples	Angelus MTA **Bond strength** in Mpa Group 1 (n = 10)	Neoputty MTA **Bond strength** in Mpa Group 2(n = 10)
1	6.702	25.371
2	9.071	21.559
3	10.475	14.675
4	11.884	19.038
5	11.640	19.602
6	8.135	24.269
7	5.993	17.132
8	9.927	24.631
9	11.276	17.242
10	7.456	22.692

Graph 2: The Bond Strength required to push-out each of the specimens



Graph 3: Mean bond strengths between the 2 study groups

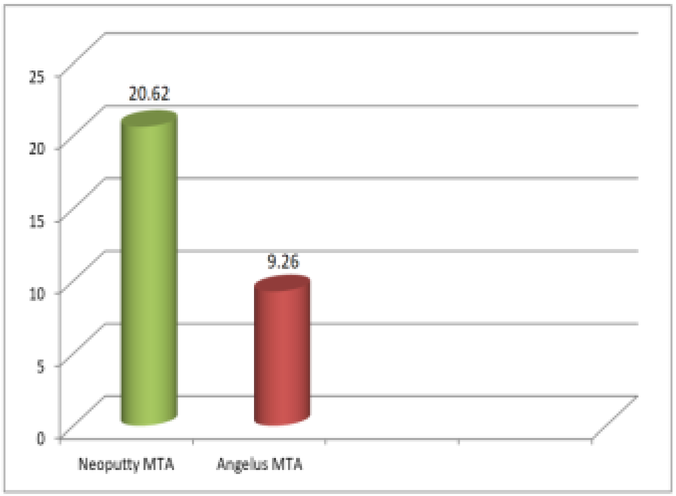


Figure 1: The Bioactive Bio-ceramic NeoPUTTY MTA (NuSmile, Houston, TX, USA)

Figure 2: A 3 mm apical root section was removed perpendicular to the long axis of root with a water-cooled low-speed diamond saw (Isomet; Buehler, Lake Bluff, NY, USA) to simulate open apex.

Figure 3: A 2mm thickness slice from the apical side of the remaining root of each tooth was cut with a water-cooled low-speed diamond saw (Isomet; Buehler, Lake Bluff, NY, USA) perpendicular to the long axis of the root.

Figure 4: The 2mm thickness slice from the apical side of the remaining root of each tooth, cut with a water-cooled low-speed diamond saw (Isomet; Buehler, Lake Bluff, NY, USA) perpendicular to the long axis of the root.

Figure 5: Canals of all the 2mm dentin sections were enlarged to a standardized cavity size of 1.3mm diameter using SF 31 straight bur (head diameter 1.3mm)

Figure 6 A:

Figure 6 (a, b): A 2mm tooth section showing the root canal that was enlarged to a standardized cavity size of 1.3mm diameter using SF 31 straight bur (head diameter 1.3mm)

Figure 7 A:

Figure 7(a, b): The filled 2mm teeth sections

Figure 8: The universal testing machine (Instron India Pvt., Ltd.) with the stainless steel indenter of 1 mm tip diameter.

Figure 9: The stainless steel indenter with 1mm tip diameter

Figure 10: The custom-made base with a hole on which each sample was placed

Conclusion

Within the limitations of our present in – vitro study, the results can be concluded that, there was statistically significant better sealing and bonding ability for the Bioactive Bio-ceramic Neoputty MTA when compared to the Conventional MTA. The conclusions need to be substantiated by conducting studies in vivo using these materials and parameters with larger sample size.

References

1. Bajwa NK, Jingarwar MM, Pathak A. Single Visit Apexification Procedure of a Traumatically Injured Tooth with a Novel Bio-inductive Material (Biodentine). International Journal of Clinical Pediatric Dentistry. 2015 Jan-Apr; 8(1):58-61.
2. Morse DR, Larnic JO, Yesilsoy C, Apexification: review of the literature Quintessence Int. 1990; 21: 589-98.
3. Torabinejad M, Chivian N. Clinical applications of mineral trioxide aggreggate. J Endod 1999;25(3):197-205.
4. M. Parirokh, M.Torabinejad, Mineral trioxide aggregate: a comprehensive literature review--Part III: Clinical applications, drawbacks, and mechanism of action, J Endod 36(3) (2010) 400-13.
5. Katebzadeh N, Dalton BC, Trope M. Strengthening immature teeth during and after apexification J Endod. 1998;24:256–9.
6. Binnie WH, Rowe AH. A histological study of the periapical tissues of incompletely formed pulpless teeth filled with calcium hydroxide J Dent Res. 1973;52:1110–6.
7. Nasseh A. The rise of bioceramics. Endod Practice 2009; 2: 17-22. 3. Jain P, Ranjan M. The rise of biocramics in endodontics: A review. Int J Pharm Bio Sci 2015; 6(1):416-422
8. Seok -Woo Chan,Tae –Seok Oh,Hyeon –Cheol Kim Long term observation of the mineral trioxide aggregate extrusion in to the periapical lesion : a case series, International Journal of Oral Science 2013 ; 5 ,54 –57.
9. Thompson JI, Gregson PJ, Revell PA. Analysis of push-out test data based on interfacial fracture energy. J Mater Sci Mater Med1999;10:863-8.
10. Shokouhinejad N, Nekoofar MH, Iravani A, Kharrazifard MJ, Dummer PM. Effect of acidic environment on the push-out bond strength of mineral trioxide aggregate. J Endod 2010;36:871-4.
11. Aly, Y., El Shershaby, S. & El-Sherif, S. Bond strength and marginal adaptation of a novel root-end filling material. Bull Natl Res Cent **44**, 142 (2020).
12. Thompson JI, Gregson PJ, Revell PA. Analysis of push-out test data based on interfacial fracture energy.J Mater Sci Mater Med 1999;10:863-8.
13. Blinc A, Bozic M, Vengust R, Stegnar M. Methyl-methacrylate bone cement surface does not promote platelet aggregation or plasma

coagulation in vitro. Thromb Res 2004; 114: 179–84.

14. Durmus Alperen Bozkurt , Arslan Terlemez , Melek Akman The push-out bond strength of BIOfactor mineral trioxide aggregate, a novel root repair material.Restor Dent Endod. 2019 Feb;44(1):e5
15. Atmeh AR, Chong EZ, Richard G, et al: Dentin-cement interfacial interaction: calcium silicates and polyalkenoates. J Dent Res 2012; 91: 454–459. Yavari H, Samiei M, Eskandarinezhad M, et al: An in vitro comparison of coronal microleakage of three orifice barriers filling materials. Iran Endod J 2012; 7:156-60.
16. Han L, Kodama S, Okiji T: Evaluation of calcium-releasing and apatite-forming abilities of fast-setting calcium silicate-based endodontic materials. Int Endod J 2015; 48:124-130.
17. Nosrat A, Asgary S, Eghbal MJ, Ghoddusi J, Bayat-Movahed S. Calcium-enriched mixture cement as artificial apical barrier: A case series. J Conserv Dent 2011;14:427-31.
18. Juez M, Ballester ML, Berástegui E. In vitro comparison of apical microleakage by spectrophotometry in simulated apexification using White Mineral Trioxide Aggregate, TotalFill Bioceramic Root Repair material, and BioDentine. J Conserv Dent 2019 May-Jun;22(3):237-240.