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Comparative evaluation of root canal irrigants on the compressive strength of NEO MTA Plus, Biodentine and Bioaggregate Cements: An in vitro study

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Abstract

Objective: The aim of this study was to evaluate the effect of root canal irrigants on the compressive strength of hydraulic tricalcium silicate cements.

Materials and methods One hundered eighty Eppendorf tubes were be randomly divided into three experimental group(n=60) in each group.Test materials were fabricated to standardized dimensions using cylindrical polyethylene molds having internal dimensions 8 mm height and 5 mm width. The materials were prepared according to the manufacturer's instructions (n = 60):Specimens (n = 180) of tricalcium silicate materials were randomly divided — Group 1(n=60):Neo MTA PLUS powder were mixed with the liquid from the provided ampoules ; Group 2 (n=60): Biodentine was mixed in a triturator (n=60) and ;Group 3(n=60):Bioaggregate(IROOT BP PLUS) in injectable form . were exposed to one of the solutions (n = 15): Phosphate buffered saline (PBS; control), 2.5% NaOCl , 2.5% NaOCl followed by 17 % EDTA or2.5% NaOCl followed by 15 % citric acid while being suspended in PBS. Compressive strength values were evaluated after 7 days of storage. The data were statistically analyzed by two-way ANOVA and Tukey's multiple comparison test (P = 0.05).

Results Biodentine showed maximum compressive strength followed by Neo MTA plus and least by

Bioaggregate. All the irrigants affected the compressive strength of Neo MTA Plus, Biodentine, Bioaggregate to root canal dentin. With respect to irrigant PBS showed the maximum compressive strength, then by 2.5% NaOCl then by 2.5% NaOCl followed by 15% citric acid . The minimum compressive strength was noticed in 2.5% NaOCl followed by 17 % EDTA.

Conclusions: Biodentine and NeoMTA Plus and Bioaggregate did not show a significant reduction in compressive strength when exposed to NaOCl. EDTA and citric acid reduced the compressive strength of the cements tested.

Keywords: Bioaggregate, Biodentine, Citric acid, Compressive Strength, Ethylenediamenetetracetic acid, NeoMTA Plus, Sodium Hypochlorite, Tricalcium silicate cements

Introduction

Tricalcium silicate-based cements (TS) are commonly used in the scope of endodontics, including vital pulp therapy, apexification, coronal seal, perforation repair, root-end filling, and root canal sealer . The materials are hydraulic in nature, i.e., they set in the presence of moisture

MTA Plus™ has fragments which are finer in size and also have a larger area. Because of minute size of fragments, it has reduced setting time when compared to MTA. The minute particle size makes its manipulation and placement easier. MTA Plus™ kit is there to improve its washout resistance which has an optional gel as the mixing vehicle. MTA is now widely used in direct pulp capping and pulpotomy due to its sealing ability, antibacterial activity and biocompatibility. And MTA was used as apical barrier in root canals with open apex. Furthermore, MTA is used in the treatment of immature permanent teeth with necrotic pulp. Apexification or regenerative endodontics using MTA was reported. Resolution of periapical inflammation and continued root development was examined by regenerative endodontics[1].

Biodentine™ (Septodont, Saint Maur Des Fosses, France) is a high-purity calcium silicate-based dental material composed of tricalcium silicate, calcium carbonate, zirconium oxide, and a water-based liquid-containing calcium chloride as the setting accelerator and water-reducing agent It is recommended for use as a dentin substitute under resin composite restorations and an endodontic repair material because of its good sealing ability, high compressive strengths, short setting time, biocompatibility, bioactivity, and biomineralization properties. Biodentine™ promotes dentinogenesis by enrolling pulpal cells and its separation, also organizes transforming factors.It shows active intercommunication with dentin and pulpal tissues bond[2].

BioAggregate (Innovative Bioceramix , Vancouver, BC, Canada), a novel laboratory-synthesized water-based cement, is reported to present improved performance compared with MTA. As the first nanoparticular mineral cement introduced in the dental market, BioAggregate is produced under controlled conditions, resulting in a pure and fine white hydraulic cement like powder composed of contamination-free bioceramic nanoparticles[3] . It is described by its manufacturer as an insoluble, radiopaque, and aluminum-free material primarily composed of calcium silicate, calcium hydroxide, and calcium phosphate . BioAggregate has shown excellent sealing ability when used for root-end filling . Many in vitro studies have shown that BioAggregate exhibits potent antimicrobial action, excellent biocompatibility, and significant induction of bone and periodontal regeneration . Moreover, BioAggregate was recently shown to display superior local and systemic biocompatibility in vivo compared with MTA[4] .

The endodontic repair material often comes in contact with various endodontic irrigants during shaping and cleaning of the root canal system. The most commonly used irrigating agents are sodium hypochlorite (NaOCl), ethylenediaminetetraacetic acid (EDTA) and chlorhexidine whilst several other decalcifying agents such as maleic acid, citric acid, peracetic acid and antiseptics such as alexidine and octenidine have also been evaluated (Ballal et al. 2016)[5].

It has also been reported that the hydration of MTA is negatively influenced by proteolytic, and decalcifying agents (, which was reported to result in its decreased dislocation resistance when root canals were irrigated with NaOCl or EDTA. Hence, it appears reasonable that the root canal irrigation protocol is an important factor to be considered when root canals are filled with MTA-based materials[6].

In recent years several combination products have been introduced for the irrigation of the root canals. The use of combination products should simplify irrigation as the new smear layer removing 'cocktail' solutions now have a pronounced antimicrobial effect. Exposure to irrigation solutions during chemomechanical irrigation changes the chemical and mechanical properties of the root canal dentin surface and so evaluating the effect of chelating agents on the bond strength of CSC should be investigated[7].

Therefore the aim of the study is to evaluate the effects of root canal irrigants on compressive strength of Neo MTA Plus, Biodentine and Bioaggregate: An in vitro study

The null hypothesis is that none of irrigants used will affect the compressive strength of Neo MTA Plus, Biodentine, Bioaggregate

Specimen Preparation

The compressive strength testing was performed in accordance with ISO 9917–1 . Test materials were fabricated to standardized dimensions using cylindrical polyethylene molds having internal dimensions 8 mm height and 5 mm width. The materials were prepared according to the manufacturer's instructions (n = 180):

Group 1: Neo MTA PLUS powder were mixed with the liquid from the provided ampoules (n=60);

Group 2: Biodentine was mixed in a triturator (n=60) and

Group 3: Bio aggregate (IROOT BP PLUS) in injectable form (n=60).

For group 1, a 3:1 powder: liquid/ gel ratio by weight was used. BD capsules contain 0.7 g to be mixed with 0.18 mL of liquid. The materials were compacted into the tubes using an amalgam plugger, and the surface was leveled. The samples of each group were randomly divided into four subgroups (n = 15). In order to expose the cement samples to the solutions, a simple clinically relevant design was used (Fig. 1). The specimens were placed in Eppendorf tubes which contained phosphate buffered saline (PBS). The top surface was exposed to one of the following solutions for 5 min via a saturated gauze containing the same quantity (3 mL) of one of these solutions: A, phosphate buffered saline (control); B, 2.5% % NaOCl (Parcan, Septodont, Saint-Maur-desFossés Cedex, France);C- 2.5% NaOCl followed by 17 % EDTA (Pulpdent, Watertown, MA, USA), Group D ,2.5% NaOCl followed by 15 % citric acid .

Hence, the base portions of the material were exposed to PBS while the top surface was exposed to the irrigating solution to simulate the clinical situation. After 5 min of exposure, the coronal surfaces were rinsed with 3 ml of distilled water for 2 min. The assembly was placed in an incubator at 37 °C at 100 % humidity for 7 days. Subsequently, material flash from the ends of the molds was removed using a 400-grit sandpaper. Following removal of the specimens from the molds, the compressive strength was tested by placing the specimens lengthwise between the compression plates of a universal testing machine (Instron model 1011, UK) at a crosshead speed of 1 mm/s.

The force required to break the samples (in N/mm2) was evaluated. The means and standard deviations were calculated and the data was analyzed statistically using a Two Way analysis of variance (with material and irrigating solution as variables; and compressive strength as the outcome measure) and Tukey multiple comparison post hoc with a significance level set at P = 0.05

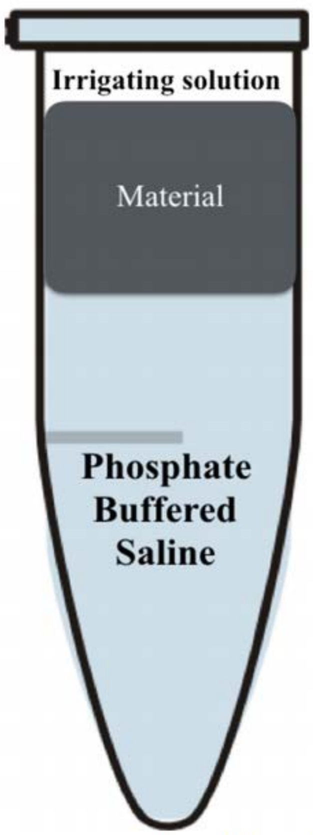


Fig. 1 Schematic representation of the study design showing placement of the cement samples within the Eppendorf tube containing phosphate buffered saline, with the coronal end being exposed to the irrigating solutions

Results

Overall, the compressive strength of Biodentine & Neo MTA plus were significantly higher than that among Bioaggregate groups. No statistically significant difference could be found among Neo MTA plus & Biodentine.

Overall, the compressive strength of materials was significantly higher among Control irrigant (PBS) and 2.5% NaOCl subgroups as compared to that among other subgroups, i.e., 2.5%NaOCl followed by 15% citric acid and 2.5%NaOCl followed by 17% EDTA. No statistically significant difference could be found among Control & 2.5% NaOCl. Similarly, no statistically significant difference could be found among 2.5% NaOCl followed by 15% Citric acid and 2.5% NaOCl followed by 17% EDTA.

Graph 1 is showing the descriptive of Compressive strength according to groups (material) & subgroups (Irrigant).

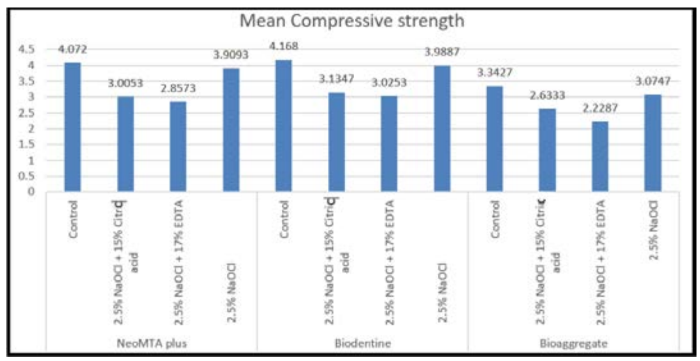
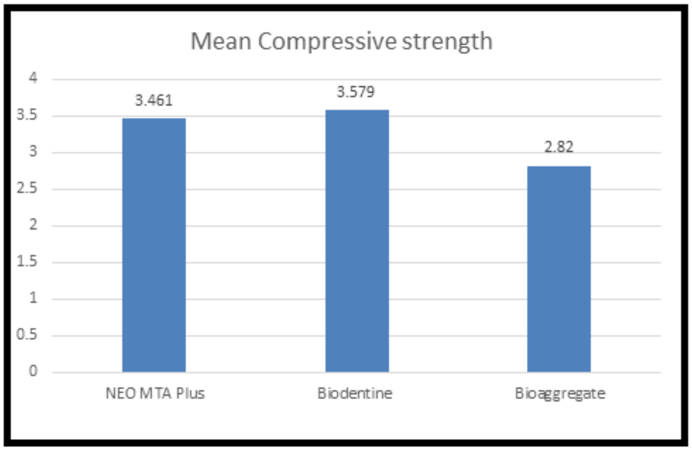


Table 1: Intergroup comparison of compressive strength (MPa, means ± standard deviations) of calcium silicate cements

1. Based on material				
Dependent Variable: compressive strength				
material	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
NEO MTA Plus	3.461	.079	3.305	3.617
Biodentine	3.579	.079	3.423	3.735
Bioaggregate	2.820	.079	2.664	2.976



Graph 2: Intergroup comparison of compressive strength (MPa, means ± standard deviations) of calcium silicate cements.

Discussion

This study evaluated the compressive strength of hydraulic tricalcium silicate after exposure to root canal irrigating solutions. In clinical situations such as apexification or perforation repair, the irrigants could come in contact with partially set MTA. There is evidence to show that exposure to acidic and alkaline pH has an impact on the physico-mechanical properties of tricalcium based cements[8] .However, these studies did not test root canal irrigating solutions with acidic or alkaline pH and combination of irrigants . Furthermore, because the minimum contact time between these irrigating agents and the cement to bring about deterioration of material properties is unknown, this study used a 5- min contact period[9].

Therefore this study aimed to evaluate push out bond strength of Neo MTA plus, biodentine and bioaggregate after application of various intracanal irrigants

Thus the null hypothesis was rejected as all irrigants affected the compressive strength of Neo MTA Plus, Biodentine, Bioaggregate to root canal dentin.

In this study, the compressive strength of Biodentine (BD) was significantly higher than the other materials tested, this was followed by NeoMTA Plus, and Bioaggregate respectively. The microstructure of MTA based materials has been shown to be less dense than Biodentine, which may be attributed to the lower compressive strength values. Although the particle size may be considered a possible determinant of this result, it is also important to consider the other differences that exist between these cements in the powder component and nature of the liquid. Biodentine powder is composed of tricalcium silicate and calcium carbonate, with zirconium oxide as the radiopacifier. The liquid contains water, calcium chloride, and a water soluble polymer. NeoMTA Plus powder contains tricalcium silicate, dicalcium silicate, calcium sulfate, and silica, with tantalite as the radiopacifier. The water-based gel contains accelerators for setting and film-forming polymers, but no salts[10]

Grech L, Mallia B, Camilleri J evaluated the physical properties of tricalcium silicate cement-based root-end filling materials. Biodentine demonstrated a high washout, low fluid uptake and sorption values, low setting time and superior mechanical properties. The fluid uptake and setting time was the highest for Bioaggregate. Camilleri reported that the set mass of BD consisted of particles of approximately 5 μm embedded in a calcium silicate hydrate matrix[11].

The results of present study is in accordance with study conducted by **Govindaraju L, Neelakantan P, Gutmann JL.** They evaluated effect of root canal irrigating solutions on the compressive strength of tricalcium silicate. Biodentine (BD) showed significantly higher compressive strength than the other materials ($P < 0.05$) in the control group[6].

In the present study Bioaggregate showed the least compressive strength. Bioaggregate has very similar composition than MTA, but it is aluminum free and had different opaquers. Different radiopaquers can change the physical and chemical behavior of MTA and decrease the compressive strength. The high water-to-powder ratio of Bioaggregate seems to have contributed to its low compressive strength.The results of present study is in accordance with study conducted by **Chakravarthy Y, Raj AM**[12]

In our study application of 2.5 % NaOCl was not associated with decrease in compressive strength , which may be explained by the fact that contact of NaOCl with MTA results in a hydration mechanism devoid of the Portlandite phase that could have decreased the compressive strength [13]. An interesting finding in this study was that NaOCl did not significantly reduce the compressive strength of the novel Tricalcium silicate. This finding supports the need for analyzing the role of radiopacifiers (zirconium oxide in biodentine and tantalite in NeoMTA Plus) in the hydration mechanisms of these materials. BD also contains calcium carbonate (15 %) that enhances the microstructure of the cement by serving as nucleation sites for the calcium silicate hydrate gel . This could have resulted in better compressive strength

Similarly **Govindaraju L, Neelakantan P, Gutmann JL** evaluated effect of root canal irrigating solutions on the compressive strength of tricalcium silicate cements.They found that Biodentine and NeoMTA Plus did not show a significant reduction in compressive strength when exposed to NaOCl[5].

In comparison to control (PBS) and 2.5 % NaOCl there was decrease in compressive strength of tricalcium cements by application of 2.5 % NaOCl followed by 10% citric acid and 2.5 % NaOCl followed by 17% EDTA groups in all the tested root end filling however there was no statistical difference.

EDTA brought about a significant reduction of compressive strength of all the materials . Therefore, irrespective of the composition or particle size of the cement, EDTA can reduce the compressive strength of hydraulic TS. This may be due to its chelating action, which interferes with the formation of calcium silicate hydrate gel[14,15,].

15% citric acid is calcium depleting organic acids with a pH of 2.15, the calcium-depleting nature of this acid may have the potential to decrease the strength of MTA based cements by disrupting the crystallization of C-S-H[16].

The results of present study was in accordance to the study performed **by Ballal NV, Mishra P, Rao S, Upadhyay ST** which evaluated the effects of chelating agents on the microhardness of Biodentine. They found that the specimens treated with 17% EDTA showed significantly lower hardness when compared to Smear OFF and distilled water. This may be attributed to chelation of the calcium ions released from BD by EDTA during hydration which lowers its hardness value due to poor crystallization[17].

There is significant decrease in the compressive strength of material after exposure to acidic environment. Literature has indicated that lower pH environments affects the physical and chemical properties of hydraulic cements. Low pH affects the hydration reaction of the material and that the more acidic the surrounding solution during the setting process, the more extensive is the porosity of set material(Neo MTA Plus ,Biodentine , Bioaggregate)[18].

An important methodological aspect that was incorporated in this study design was suspension of the samples in PBS. This was performed in order to simulate the clinical situation where these cements come in contact with tissue fluid. It is possible that these materials may have yielded much lower compressive strength values in the absence of this consideration. In essence, the compressive strength of the materials varied with the irrigating solution. This also varied with the composition of the cements tested. This implies that the hydration mechanics of the cements are influenced by the irrigating solutions. The exact changes that occur in these materials are not within the scope of this work and needs further characterization. Future research should also investigate how the compressive strength of these cements varies with time.

Conclusion

Therefore, within the constraint of the study, it can be concluded that:

- Biodentine showed maximum compressive strength followed by Neo MTA plus and least by Bioaggregate
- All the irrigants affected the compressive strength of Neo MTA Plus, Biodentine, Bioaggregate to root canal dentin.
- With respect to irrigant 2.5% NaOCl showed the maximum and 2.5% NaOCl followed by 17 % EDTA showed minimum compressive strength of tricalcium silicate cements used.
- Both 17 % EDTA and 15 % citric acid showed similar reduction in compressive strength.
- Future research should focus on the exact mechanisms by which irrigants influence the mechanical properties of hydraulic tricalcium silicate cements and how the compressive strength of these cements varies with time.

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