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AN IN VITRO COMPARATIVE EVALUATION OF COMPRESSIVE STRENGTH OF THREE DIFFERENT PERFORATION REPAIR MATERIALS

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ABSTRACT

The aim of this study was to evaluate the compressive strength of MTA and two novel tricalcium silicate-based endodontic materials, Biodentine and Bioaggregate. The compressive strength of the test materials were determined using the Universal Testing Machine. Each material was mixed and placed in a split stainless steel mold (6 mm in diameter and 4 mm in height) within 2 minutes after the start of mixing. The materials were divided into **3** experimental groups and the compressive strength of each group was measured at 1 hour, 1 day, 1 week, 2 weeks, 3 weeks and 4 weeks. The maximum load required to fracture each specimen was determined. The ultimate compressive strength (USC) was calculated in megapascals (MPa) by using the following formula: UCS = $4F/\pi D^2$ where F = maximum applied load in Newton and D = mean diameter of specimens in millimetres. The compressive strength of Bioaggregate was significantly lower than that of MTA and Biodentine. Within the limitations of this study, it was concluded that Biodentine have superior strength than MTA and Bioaggregate.

Keywords: Bioaggregate, Biodentine, Compressive strength, MTA.

INTRODUCTION

Perforation is a pathological communication between the root canal system and the supporting periodontal tissues of the teeth. It may occur from resorptive defects, caries or iatrogenic events during endodontic treatment. It has been reported as the second leading cause of endodontic failures following obturation [1]. Various materials have been used to repair the perforation. Some criteria for the ideal repairing material include biocompatibility, sealing ability, good handling properties, non cytotoxicity and the ability to induce osteogenesis and cementogenesis [2].

Different materials used to seal perforations include amalgam, zinc oxide eugenol- based materials, calcium hydroxide, glass – ionomer, MTA, Biodentine, super- EBA, etc. Mineral trioxide aggregate (MTA) is a calcium silicate based endodontic material introduced by Lee and Torabinajed in 1993 at Loma Linda University. MTA is a mixture of refined Portland cement and bismuth oxide, and is reported to contain trace amounts of Silicon Dioxide (SiO_2), Calcium Oxide (CaO), Magnesium Oxide (MgO), Potassium Sulfate (K_2SO_4) and Sodium Sulfate (Na_2SO_4). MTA poses two important clinical features, a) it sets in the presence of moisture e.g. tissue fluids b) it exerts vast antimicrobial action due to its alkaline pH (approximately pH = 12) [3]. This high pH is probably due to the existence of calcium oxides in the composition of the material [4]. The material's setting process is described as a hydration reaction of tricalcium silicate and dicalcium silicate which the latter is being responsible for the development of the material strength. MTA's compressive strength and displacement resistance show increasing levels for up to twenty one days in the presence of moisture, while its microhardness and hydration behavior seems to be affected by the low pH of the inflammatory environments [4]. However, the main drawbacks of MTA include potential presence of toxic elements in the final product, difficulty in handling, long setting time and high material

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cost [6-8].

Biodentine is an "in-house synthesized" Tricalcium Silicate to guarantee high purity. Adding calcium chloride ($CaCl_2$) to the liquid component accelerates the system, therefore decreasing the liquid content in the system decreases the setting time to harden within nine to twelve minutes [9-11]. It shows apatite formation after immersion in phosphate solution, indicative of its bioactivity. The powder mainly consists of tri-calcium silicate (C_3S), di-calcium silicate, calcium carbonate and oxide, iron oxide and zirconium oxide for radiopacity. The material exhibits great biological properties, similar to MTA levels, such as biocompatibility and minimum toxicity. According to the manufacturer, Biodentine™ exhibits lower porosity than MTA and as higher compressive strength in the first hour period [1].

Bioaggregate is a new bioceramic root repair and root – end filling material composed of a powder component consisting of tricalcium silicate, dicalcium silicate, tantalum pentoxide, calcium phosphate monobasic and amorphous silicon oxide and a liquid component of deionized water [6]. This hydrophilic bioaggregate promotes cementogenesis and forms a hermetic seal inside the root canal. It is effective in clinically blocking the bacterial infection. It is indicated in repair of root perforation, root resorption, root end filing, apexification, pulp capping. It has excellent biocompatibility with the vital periradicular tissue [8].

All these dental restorative materials present an ideal combination of good physical, chemical and biological properties. Nevertheless compressive strength is a major factor that contributes in improving the quality of material at the time of masticatory forces. It has a particularly important role in the mastication process since several of the masticatory forces are of compressive nature [7]. All ideal endodontic materials should be able to tolerate the functional forces during mastication. Compressive strength is regarded as one of the most important physical characteristics. It is the highest vertical compressive load that a material can stand before fracture and is measured by universal testing machine. Compressive strength of a given biomaterial over time is an indicator of setting reaction and stability of the material. The maximum resistance to compression is calculated by the original cross-sectional area of the test specimens and the maximum force applied [1].

MATERIALS AND METHODS

The compressive strength of the test materials was determined by using the method recommended by the ISO 9917. The materials are divided into 3 experimental groups, each time group consists of 5 samples each, so that there are 15 specimens for each time groupandisassigned as n = 5 Group I – Biodentine (BD), Group II – Mineral Trioxide Aggregate (MTA), Group III – Bioaggregate (BA)

Specimen preparation

The specimens are prepared with dimensions of 4.0mm in length and 6.0mm in diameter, using a two-part stainless steel cylindrical mold. The mold is placed on a glass slab and a cellophane paper is placed under the mould to get a flat surface [2].

Each group of cement is mixed till it become thick in consistency. Then the thick paste is mulled to avoid air bubbles and microcracks which can reduce the compressive strength. Within 2 minutes after the start of mixing the material is loaded with hand pressure into the mold till it obtained a flat surface on the top of the mold. After setting, both ends of the specimen are abraded with fine grit sand paper and divided into six groups (1 hour, 1 day, 1 week, 2 weeks, 3weeks and 4 weeks) of 5 samples each and stored in 100 % relative humidity at $37 \pm 1^{o}C$ and then removed from the mold and stored in distilled water at $37 \pm 1^{o}C$ in an incubator for different periods of time prior to compressive strength testing to simulate the clinical condition.

Measurement of compressive strength

Compressive strength of the specimens should be measured at a set time of 1 hour, 1 day, 1 week, 2 weeks, 3 weeks and 4 weeks on the Universal Instron Testing Machine, at a cross–head speed of 0.5 mm/min and ultimate compressive strength (UCS) is calculated in megapascals (MPa) from the formula : $UCS = 4F/ \pi D^2$ where F = maximum applied load in Newton (N) and D = mean diameter of specimens in millimetres (mm).

STATISTICAL ANALYSIS

Two-way analysis of variance (ANOVA) followed by Paired t - test was used to determine statistically significant differences in compressive strength according to the time and test materials. A p-value < 0.001 was considered statistically significant.

RESULTS

As shown in Table 1, the compressive strength of Biodentine was significantly higher than that of MTA and Bioaggregate at all time intervals ($p < 0.001$). There were no significant changes in the compressive strength of Biodentine with time. The compressive strength of MTA increased significantly with time. The compressive strength of Bioaggregate was significantly lower than that of MTA and Biodentine at all time points ($p < 0.001$).

Table 1. Compressive strength (MPa) of test materials

		Group				
		BD	**MTA**	**BA**	**F (ANOVA)**	**p**
1 Hour	**Mean**	147.82[a]	0.23[b]	14.62[c]	2343.75	< 0.001**
	SD	6.07	0.09	2.36		
1 Day	**Mean**	183.88[a]	44.34[b]	18.82[c]	911.91	< 0.001**
	SD	10.35	4.64	1.09		
1 Week	**Mean**	242.69[a]	59.01[b]	22.10[c]	1059.45	< 0.001**
	SD	12.97	5.23	1.45		
2 Weeks	**Mean**	253.56[a]	65.77[b]	25.35[c]	2966.77	< 0.001**
	SD	7.05	4.87	1.24		
3 Weeks	**Mean**	264.01[a]	83.89[b]	26.20[c]	531.59	< 0.001**
	SD	19.99	5.71	1.41		
4 Weeks	**Mean**	296.96[a]	87.64[b]	28.37[c]	8536.33	< 0.001**
	SD	4.74	3.39	1.00		

** Highly Significant

Values are expressed as Mean and SD, standard deviation (n = 5 for each group).

Table 2. Paired T – test values for group I

BD		**Mean**	**SD**	**Paired t**	**p**
Pair 1	1 Hour	147.82	6.07	4.93	0.008**
	1 Day	183.88	10.35		
Pair 2	1 Hour	147.82	6.07	11.28	< 0.001**
	1 Week	242.69	12.97		
Pair 3	1 Hour	147.82	6.07	18.44	< 0.001**
	2 Weeks	253.56	7.05		
Pair 4	1 Hour	147.82	6.07	10.42	< 0.001**
	3 Weeks	264.01	19.99		
Pair 5	1 Hour	147.82	6.07	43.27	< 0.001**
	4 Weeks	296.96	4.74		
Pair 6	1 Day	183.88	10.35	24.43	< 0.001**
	1 Week	242.69	12.97		
Pair 7	1 Day	183.88	10.35	36.30	< 0.001**
	2 Weeks	253.56	7.05		
Pair 8	1 Day	183.88	10.35	13.03	< 0.001**
	3 Weeks	264.01	19.99		
Pair 9	1 Day	183.88	10.35	21.06	< 0.001**
	4 Weeks	296.96	4.74		
Pair 10	1 Week	242.69	12.97	2.90	0.044*
	2 Weeks	253.56	7.05		
Pair 11	1 Week	242.69	12.97	2.77	0.050*
	3 Weeks	264.01	19.99		
Pair 12	1 Week	242.69	12.97	9.16	0.001**
	4 Weeks	296.96	4.74		
Pair 13	2 Weeks	253.56	7.05	1.59	0.186
	3 Weeks	264.01	19.99		
Pair 14	2 Weeks	253.56	7.05	9.75	0.001**
	4 Weeks	296.96	4.74		
Pair 15	3 Weeks	264.01	19.99	3.39	0.028*
	4 Weeks	296.96	4.74		

* Significant at 5 %; ** Significant at 1 % (Highly Significant)

Table 3. Paired T – test values for group II

MTA		Mean	SD	Paired t	p
Pair 1	1 Hour	0.23	0.09	21.49	< 0.001**
	1 Day	44.34	4.64		
Pair 2	1 Hour	0.23	0.09	24.83	< 0.001**
	1 Week	59.01	5.23		
Pair 3	1 Hour	0.23	0.09	29.64	< 0.001**
	2 Weeks	65.77	4.87		
Pair 4	1 Hour	0.23	0.09	32.36	< 0.001**
	3 Weeks	83.89	5.71		
Pair 5	1 Hour	0.23	0.09	56.38	< 0.001**
	4 Weeks	87.64	3.39		
Pair 6	1 Day	44.34	4.64	3.75	0.020*
	1 Week	59.01	5.23		
Pair 7	1 Day	44.34	4.64	6.11	0.004**
	2 Weeks	65.77	4.87		
Pair 8	1 Day	44.34	4.64	8.80	0.001**
	3 Weeks	83.89	5.71		
Pair 9	1 Day	44.34	4.64	15.48	< 0.001**
	4 Weeks	87.64	3.39		
Pair 10	1 Week	59.01	5.23	6.98	0.002**
	2 Weeks	65.77	4.87		
Pair 11	1 Week	59.01	5.23	17.48	< 0.001**
	3 Weeks	83.89	5.71		
Pair 12	1 Week	59.01	5.23	13.33	< 0.001**
	4 Weeks	87.64	3.39		
Pair 13	2 Weeks	65.77	4.87	10.46	< 0.001**
	3 Weeks	83.89	5.71		
Pair 14	2 Weeks	65.77	4.87	14.94	< 0.001**
	4 Weeks	87.64	3.39		
Pair 15	3 Weeks	83.89	5.71	1.71	0.162
	4 Weeks	87.64	3.39		

* Significant at 5 %; ** Significant at 1 % (Highly Significant)

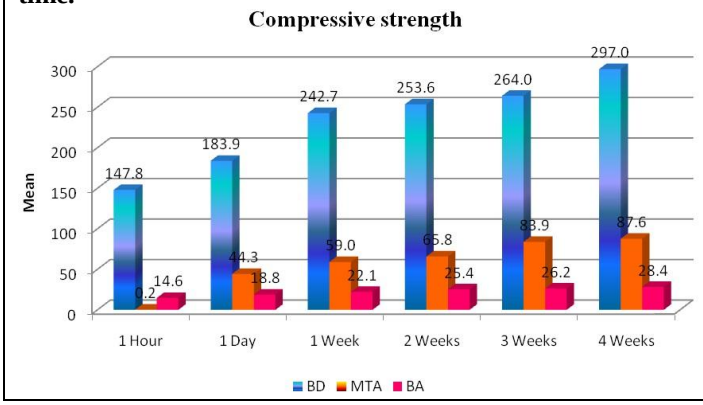
Table 4. Paired T – test values for group III

BA		Mean	SD	Paired t	p
Pair 1	1 Hour	14.62	2.36	3.39	0.028*
	1 Day	18.82	1.09		
Pair 2	1 Hour	14.62	2.36	8.66	0.001**
	1 Week	22.10	1.45		
Pair 3	1 Hour	14.62	2.36	6.89	0.002**
	2 Weeks	25.35	1.24		
Pair 4	1 Hour	14.62	2.36	7.92	0.001**
	3 Weeks	26.20	1.41		
Pair 5	1 Hour	14.62	2.36	11.83	< 0.001**
	4 Weeks	28.37	1.00		
Pair 6	1 Day	18.82	1.09	3.26	0.031*
	1 Week	22.10	1.45		
Pair 7	1 Day	18.82	1.09	9.55	0.001**
	2 Weeks	25.35	1.24		
Pair 8	1 Day	18.82	1.09	17.61	< 0.001**
	3 Weeks	26.20	1.41		
Pair 9	1 Day	18.82	1.09	13.04	< 0.001**
	4 Weeks	28.37	1.00		

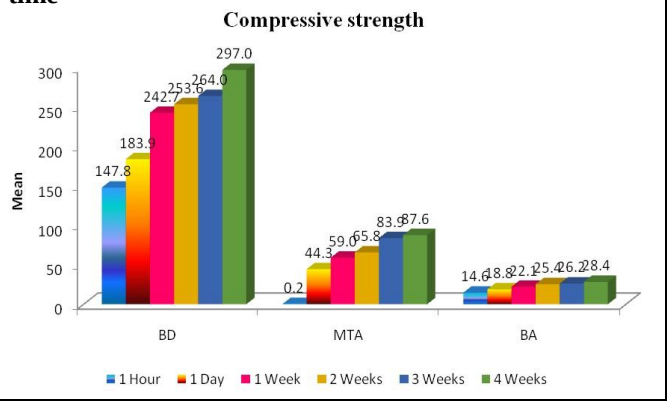
Pair 10	1 Week	22.10	1.45	3.12	0.036*
	2 Weeks	25.35	1.24		
Pair 11	1 Week	22.10	1.45	4.01	0.016*
	3 Weeks	26.20	1.41		
Pair 12	1 Week	22.10	1.45	14.22	< 0.001**
	4 Weeks	28.37	1.00		
Pair 13	2 Weeks	25.35	1.24	1.16	0.311
	3 Weeks	26.20	1.41		
Pair 14	2 Weeks	25.35	1.24	4.21	0.014*
	4 Weeks	28.37	1.00		
Pair 15	3 Weeks	26.20	1.41	3.40	0.027*
	4 Weeks	28.37	1.00		

* Significant at 5 %; ** Significant at 1 % (Highly Significant).

Graph 1. Compressive strength of three groups against time.



Graph 2. Compressive strength of three groups against time



DISCUSSION

An ideal root end filling material should present an ideal combination of good physical, chemical and biological properties [16]. Nevertheless compressive strength is a major factor that contributes in improving the quality of material at the time of masticatory forces [1].

According to Torabinejad *et al.*, the compressive strength of MTA was 40 MPa after 24 hours and 67.3 MPa after 3 weeks [16]. Likewise, in the present study, the compressive strength of MTA increased with time. The compressive strength values of Bioaggregate showed a slight increase with time. Unlike MTA and Bioaggregate, the compressive strength of Biodentine did not increase with time. Instead, it had the highest compressive strength among the three materials after 24 hours. The compressive strength of Bioaggregate was significantly lower than that of MTA and Biodentine ($p < 0.001$).

The strength of cements depends primarily on the water-to-powder ratio [15]. The high water-to-powder ratio of Bioaggregate seems to have contributed to its low compressive strength. The compressive strength of Biodentine was significantly higher than that of MTA and Bioaggregate ($p < 0.001$) [16]. Clinically, root-end filling materials do not bear direct pressure; however, materials used for pulp capping or perforation in the gingival third area bear occlusal pressure. Therefore, it is important to consider the compressive strength of materials placed on the occlusal surfaces.

CONCLUSION

According to present in-vitro study, following conclusions have been drawn, The compressive strength of MTA and Bioaggregate increased with time. Unlike MTA and Bioaggregate, Biodentine had the highest compressive strength after 24 hours. Among the three materials the compressive strength of Bioaggregate was significantly lower.

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Nil

CONFLICT OF INTEREST

None

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