ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at: www.ijdsir.com

Volume – 5, Issue – 6, December - 2022, Page No. : 115 - 122

An in - vitro evaluation of the solubility of MTA using various chemical solvents

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Citation of this Article: Dr. Jeeba Sabu, Dr. Vanamala N, Dr. B S Keshava Prasad,"An in - vitro evaluation of the solubility of MTA using various chemical solvents", IJDSIR- December - 2022, Vol. – 5, Issue - 6, P. No.115– 122.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract:

Mineral trioxide aggregate (MTA) is an excellent biocompatible material however its prolonged setting time and the difficulty in retrieving it from the root canal space are its major drawbacks. MTA being alkaline in nature can interact with acids or chemicals and disintegrate. The aim of this in vitro study was to assess the effect of various chemical solvents on the dissolution of set MTA.

Keywords: Carbonic acid, Hardness test Mineral Trioxide aggregate, Scanning Electron Microscopy,

Introduction

The past decades have seen several changes when it comes to the way Endodontics is practiced. These changes can be attributed to three main factors – the increased interest of the patients, the new materials that have found their place in the market space, and the novel techniques that have been introduced.[1]Bio ceramic materials are considered a magnanimous entity in the field of endodontics which has changed the prognosis of cases that were once considered impossible to treat. Mineral Trioxide Aggregate (MTA) is one such remarkable biocompatible material that has exciting and different clinical applications.[1] It has been used in different areas of clinical practice such as pulp capping, partial pulpotomy, perforation and resorption repair, root-end filling material, etc. The introduction of MTA by Dr. Mahmoud Torabinejad into the field of endodontics in 1993 was considered a revolution, as it prepared the clinicians better for difficult clinical scenarios.[2] In the year 1998, it was approved for endodontic use by the U.S. Food and Drug Administration[3]. MTA is basically a mixture of three powder ingredients: Portland cement (75%), bismuth

oxide (20%), and gypsum (5%)[4].Apart from the wide range of applications, MTA is now also being preferred over the conventional gutta percha obturations due to the several favourable properties[5].A few indications for Mineral Trioxide Aggregate obturations include - Endodontic Retreatment cases,MTA Obturation for Dens in Dente, Root Canal Obturation before Endodontic Surgery, Teeth with Open Apices, Apexification and Perforation repair, etc.[5]However, it is a known fact that no material is perfect. MTA has difficult handling properties and requires practice to achieve optimum results without which there can be the formation of voids.

These voids may act as portals for the entry of microorganisms and their by-products resulting in leakage and an unfavourable outcome. Furthermore, retrieval might also be necessary in cases where satisfactory healing has not occurred.[6] However, once this material sets it forms a hard-set mass making its retrievability tough in retreatment cases.

Literature has suggested that the use of ultrasonic instruments for the removal of hard pastes is effective to a certain extent but it has limited use as it can only be used in canals without curvature and there is always a risk of instrument separation.[7]Thus, the need to have a solvent for MTA has been stressed in previous studies.Several in vitro studies have suggested that an acidic pH has the potential to alter and weaken the microstructure of tricalcium silicate cement.[8]

A few materials like 37% Hydrochloric acid, 2% Acetic acid, 5.25% Sodium hypochlorite, Carbonic acid, 2 % Chlorhexidine Gluconate, and 17 % EDTA have been tried according to the past literature.[9] Clinically, an acidic pH also stands a chance of weakening the dentin and decreasing the overall tooth strength. Thus, a suitable solvent that should be considered for MTA dissolution would be one that effectively reduces the microhardness of the material without a significant negative effect on the root dentin.

Vinegar is a popular food preservative of natural origin that has been in use for thousands of years, and due to its beneficial health effects, it is of interest to the field of medicine. [10]. Apple cider vinegar, which is made from fermented apple juice and contains acetic and maleic acid, has been found to reduce approximately 30% of the Enterococcus faecalis cell population along with its ability to remove the smear layer.[11,12]

It has an acidic pH of 2-3 which could have a positive effect in reducing the microhardness of the set MTA and at the same time studies have suggested no decrease in dentin microhardness when used as an endodontic irrigant.[13]

Thus, this article focuses on the use of Apple cider vinegar as a solvent for MTA dissolution as it has been found successful in weakening Portland cement which has a similar composition to that of MTA. In addition, with its acidic pH of 2-3, ACV has antibacterial properties while being non-detrimental to the dentin microhardness which makes it a safe choice.[13] Along with this, Carbonic acid was also selected as a potential solvent as it is a weak acid (pH of 5.48) and a component of blood, and the exposure of which makes Portland cement porous.

The aim of this study was to assess the dissolving ability of Apple Cider Vinegar, carbonic acid, and saline on set MTA. A quantitative analysis was carried out using Vickers microhardness testing to measure the microhardness values of MTA following the exposure to the said solvents and a qualitative analysis was done to observe the surface changes using scanning electron microscopy.

Materials and methods

Methodology for evaluating the microhardness of set mineral trioxide aggregate

30 hollow cylindrical stainless-steel molds of 5 mm height and 6 mm internal diameter were made. Surgical gel foam was placed on one end and moistened to simulate the clinical scenario. The white MTA powder was mixed with sterile water on a glass slab using a cement mixing spatula at a powder to liquid ratio of 3: 1, which had a creamy consistency [Figure1]. This mix was then immediately condensed into the custom-made molds [Figure 2, 4]. A moistened cotton pellet was kept on top of the condensed WMTA which was then stored in a humidor [Figure 3].

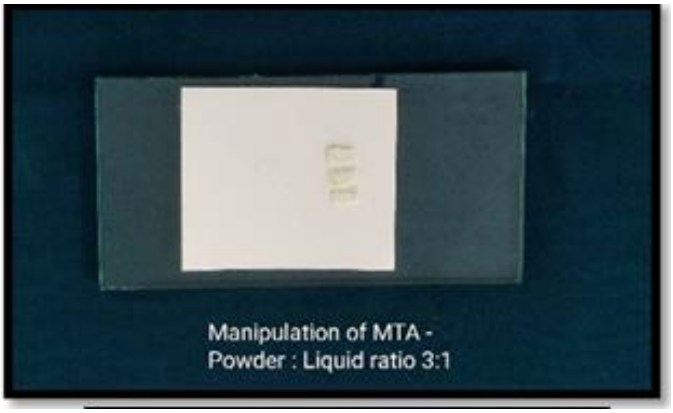


Fig 1: Manipulation of MTA

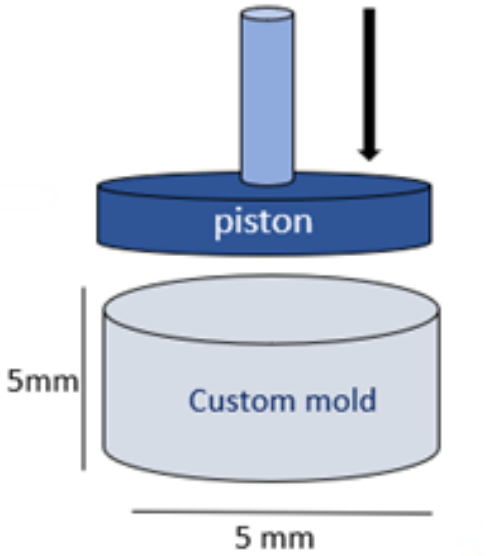


Fig 2: MTA Mix condensed into molds.

Fig 3: A Custom-made humidor with digital hygrometer to maintain the humidity at 99%

Fig 4: MTA condensed in custom-made stainless-steel molds

After storage in the humidor, all the samples were examined for cracks, defects, or gaps between the material and stainless-steel mold. Any such defective MTA blocks were eliminated from the study. The specimens were divided into three groups depending on the solvent used. [Figure 5,6]

- Group 1 – Apple Cider Vinegar [N= 10]
- Group 2– Carbonic acid [N= 10]
- Group 3 – Saline (Control group) [N= 10]

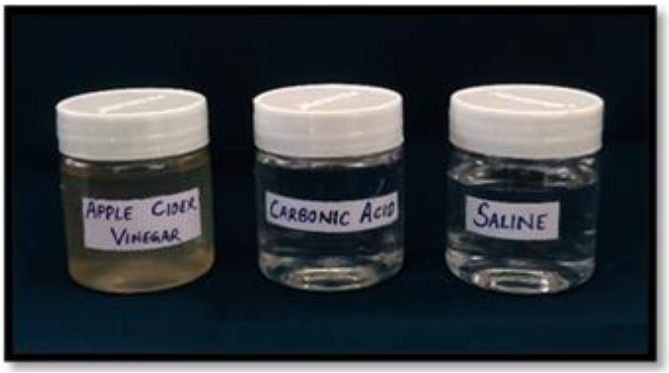


Fig 5: chemical solvents

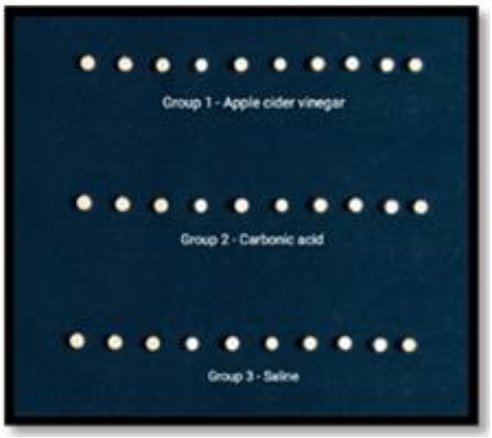


Fig 6: Three groups of MTA blocks exposed to three different solvents

The specimens from each group were tested after 21 days of setting by using the Vickers microhardness testing machine. The Vickers microhardness tester that had a square-based diamond indenter with a full load of 50 g for 5 seconds was used to check the microhardness of the set MTA blocks. The specimens in each group were exposed to the respective solvents for a total of 5 minutes at the end of day 21.

Methodology for evaluation of the microstructure of the set wmta after exposure to different solvents

The internal microstructure of the samples was examined under the scanning electron microscope after exposure of the solvents and it was then compared to the microstructure of unexposed MTA blocks to substantiate the effect of these solvents on the set mineral trioxide aggregate. Three categories of these blocks were examined.

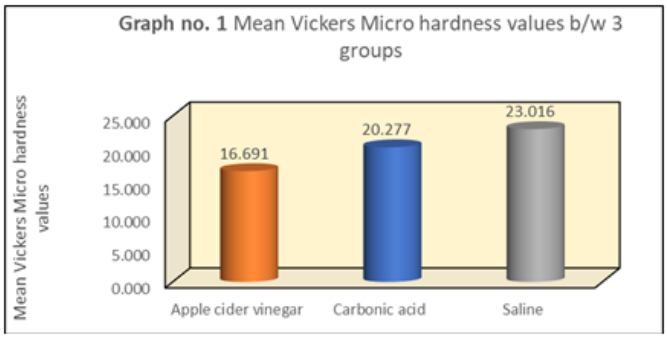
1. Before exposure to any solvent, to observe the normal microstructure of the set MTA block (n=2)
2. After a 5-minute exposure of Apple cider vinegar, 21 days after setting of MTAS (n=2)
3. After a 5-minute exposure of Carbonic acid,21 days after setting of MTAS(n=2)

The specimens were dehydrated and sputter coated with gold before being evaluated under the scanning electron microscope to evaluate the internal microstructure of set MTA.

Results and statistical analysis

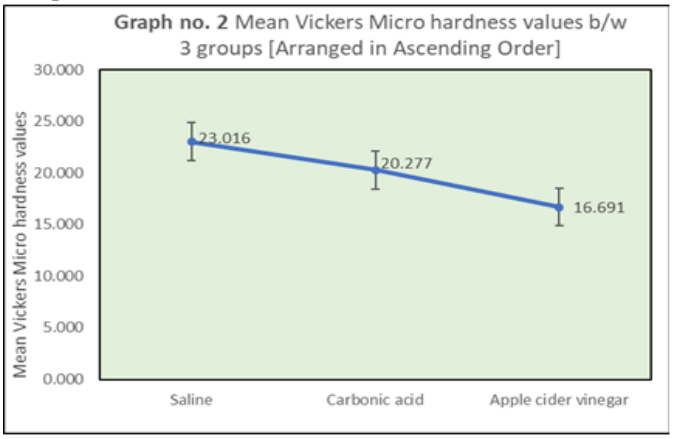
Vickers microhardness test

The test results demonstrated that the mean Vickers Micro hardness values for the Apple Cider vinegar group were 16.691 ± 1.291, the Carbonic acid group was 20.277 ± 0.437 and the saline group was 23.016 ± 0.451. This mean difference in the Vickers Micro hardness values between the 3 groups was statistically significant at P<0.001[Refer to Graph no. 1].



The test results showed that the saline group showed significantly highest Vickers Micro hardness values as compared to Apple Cider vinegar & Carbonic acid groups at p<0.001. This was followed next then by the Carbonic acid group showing significantly higher mean Vickers Micro hardness values as compared to the Apple Cider vinegar group at p<0.001. This infers that the mean Vickers Micro hardness values were significantly highest in the saline group followed by the Carbonic

Acid group & least in the Apple cider vinegar group [Refer to Graph no.2]



The comparisons of the mean differences in the Vickers microhardness test between the three groups of samples using one way ANOVA test and Tukey's post hoc analysis has been summarized in table 1 and table 2, respectively.

Table 1: Comparison of mean Vickers Micro hardness values b/w 3 groups using One-way ANOVA Test

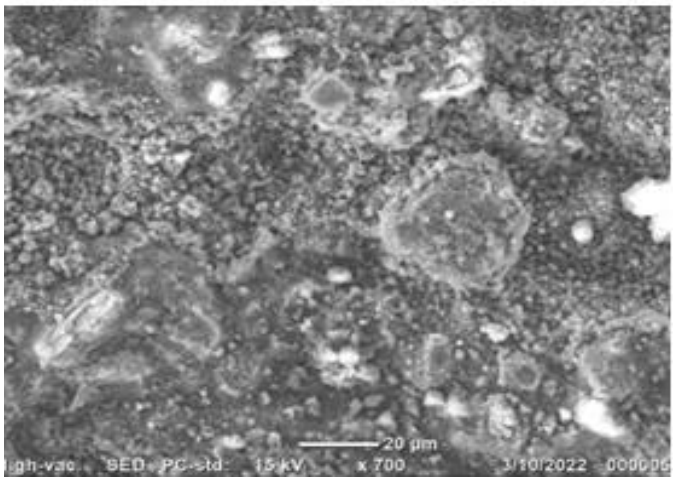
Groups	N	Mean	SD	Min	Max	P-Value
Apple cider vinegar	10	16.691	1.291	15.60	20.16	<0.001 *
Carbonic acid	10	20.277	0.437	19.77	20.98	
Saline	10	23.016	0.451	22.05	23.60	

Table 2: multiple comparison of mean diff. in Vickers nicro hardness values b/w 3 groups using Tukey's post hoc test.

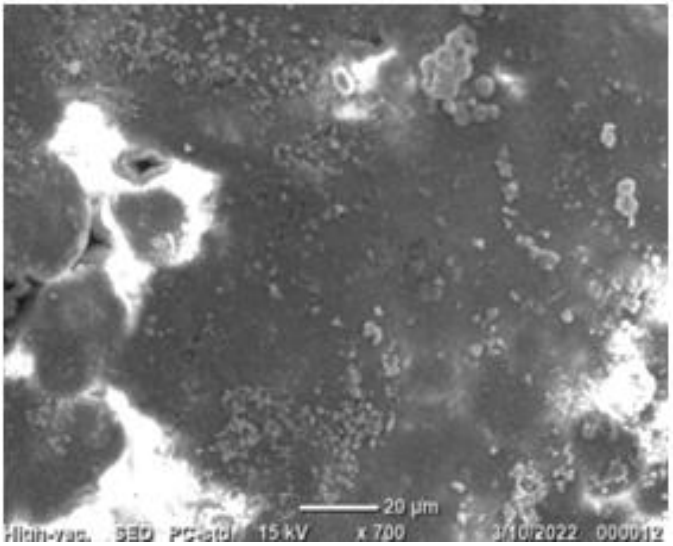
Group	(j) group	Mean diff (i-j)	95% cl for the diff		P-value
			Lower	Upper	
Apple eider vinegar	Carbonic asid	86.00	-231.51	403.51	0.72
	Saline	682.00	364.49	999.51	<0.001*
Carbonic acid	Saline	596.00	278.49	913.51	<0.001*

Scanning electron microscopy

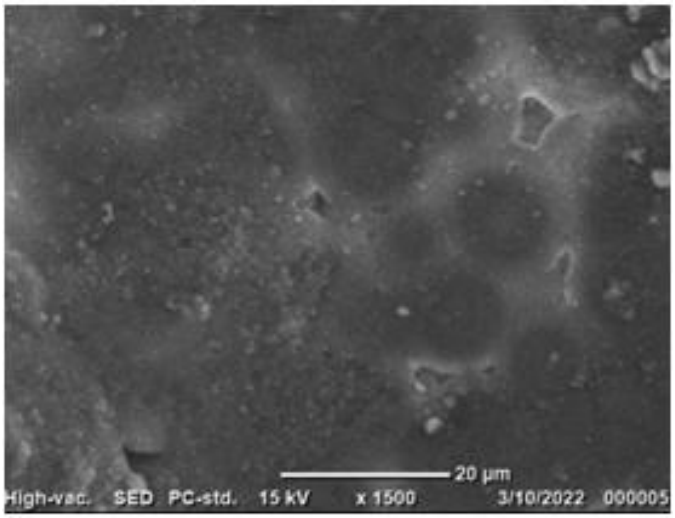
The qualitative analysis was also carried out to observe the surface changes under SEM. It was noted that the surface disintegration was the maximum in the MTA blocks exposed to the Apple cider vinegar. With apple cider vinegar as a solvent, the surface of the MTA blocks showed greater surface roughness in comparison to the group that used Carbonic acid as a solvent. The surface of the MTA block was relatively unaffected in the group unexposed to any solvents.



Group 1: Apple cider vinegar



Group 2: Carbonic acid



Group 3: Non exposed MTA.

Discussion

MTA has been proven to have a very favourable physical, chemical, and biological properties.[14] It exhibits many profound properties that are not available in other traditional materials currently used in dentistry. These properties include - bacteriostatic and potential bactericidal properties due to its unique sealing property and high initial pH, good radiopacity and dimensional stability, decreased sensitivity to moisture and blood contamination, non-irritating to the periapical tissues, and also promotes regeneration of cementum and PDL, resists bacterial microleakage toa greater degree.[5] As a canal filling material, MTA has advantageous properties, such as sealing ability and root reinforcement when compared to gutta-percha resulting in better fracture resistance. The use of MTA as an obturation material might ultimately provide long-term benefits that enhance the prognosis and retention of the natural dentition in conventional and complex therapies.[15] However, the difficulty in manipulation of MTA clinically is one of the major drawbacks of the material.[16] MTA when mixed is in the form of a slurry paste which makes its handling difficult and essentiates the need for practice in handling the material. This consistency of mixed MTA might result in the void formation and failure of the orthograde filling due to leakage from the canal space and entry of microorganisms leading to an unfavourable outcome.[6] Such failures necessitate the need for retreatments, which is a task. Different methods have been tried for the retrieval of set MTA like the use of ultrasonics and NiTi rotary files which did not provide any significant results.[9] Further, these methods cannot be tried in curved canals as there is a risk of fracture of instruments. This brought into existence the concept of solvents for dissolving the set MTA to make its retrieval easy. MTA has a very similar composition to that of Portland cement which is basically the concrete used in day-to-day life. Metallurgical studies have shown the effectiveness of apple cider vinegar in dissolving this port land cement. Thus, by applying this concept Apple cider vinegar was considered for this study. Further research on the properties of ACV revealed that it had an acidic PH of 2-3, and good antibacterial and smear layer removal properties.[12] An acidic pH has shown promising results when it comes to weakening the microstructure of MTA[9]. ACV was compared with carbonic acid in this study which is a weak acid with a pH of 5.48 and a component of blood. [17] It has been noted that MTA becomes porous on exposure to carbonic acid. [18] The quantitative analysis carried out using the Vickers microhardness test revealed that the mean Vickers Micro hardness values for the Apple Cider vinegar group were 16.691 ± 1.291, and the Carbonic acid group was 20.277 ± 0.437 and the saline group was 23.016 ± 0.451. This mean difference in the Vickers Micro hardness values between the 3 groups was statistically significant at $P<0.001$. The test results showed that the saline group showed significantly highest Vickers Micro hardness values as compared to Apple Cider vinegar & Carbonic acid groups at $p<0.001$. This was followed next then by the Carbonic acid group showing significantly higher

mean Vickers Micro hardness values as compared to the Apple Cider vinegar group at p<0.001. This infers that the mean Vickers Micro hardness values were significantly highest in the saline group followed by the Carbonic Acid group & least in the Apple Cider vinegar group. Following this, the qualitative analysis using scanning electron microscopy imaging showed that the surface changes were maximum in the MTA samples exposed to apple cider vinegar followed by those exposed to carbonic acid, and the least amount of changes were noted in the unexposed MTA group, indicating the effectiveness of ACV and carbonic acid in bringing about structural changes in the microstructure of the set white MTA thus making its retrieval relatively easy.

Conclusion

A solvent like Apple Cider Vinegar can be considered to make the retreatment cases of canals obturated with MTA possible. This will motivate more clinicians to consider MTA as an obturating material, resulting in better healing and regeneration in root canal treated teeth because of the obvious advantages noted with MTA. As an eye to the future, it should be mentioned that the present study was a preliminary study that was done to introduce an effective solvent in MTA removal. Definitely, further studies are needed to evaluate the effects of Apple cider vinegar on MTA on natural teeth samples, and In an oral environment, which if provides similar results can be a game changer in providing quality treatment to the patients.

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