Research Article

An *in vitro* application of mineral trioxide aggregate mixed with calcium hydroxide

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ABSTRACT

Background: Mineral trioxide aggregate (MTA) is the most biocompatible material used in endodontics. It is made up of hydrophilic particles that set in the presence of moisture. MTA is used in root-end filling, direct pulp capping, and apexification. The surface hardness of MTA is not very high. To improve the hardness MTA, the possibility of mixing with calcium hydroxide (CH) is explored. **Aim:** The aim is to estimate the microhardness of MTA when mixed with CH as a root-end filling material. **Materials and Methods:** Thirty extracted, (n = 30) single-rooted human teeth which includes mandibular single-rooted premolars, maxillary incisors, and canines were selected in the study. The teeth were sectioned horizontally perpendicular to the long axis of the tooth into slices with a thickness of 1.0 mm. The sliced teeth were divided into two groups – one group was filled only with MTA (Group I) and another group was filled with mineral trioxide and CH (Group II). Hardness was measured using Vickers microhardness testing machine and expressed as Vickers pyramid number (HV). **Results:** Group I showed hardness of 54.7 ± 4.53 (HV) and Group II showed hardness of 55.2 ± 5.07 (HV). Group II showed higher hardness value than Group I, and the mean difference between Groups I and II is statistically significant ($P < 0.05$). **Conclusion:** Mixing CH with MTA can improve its properties. In the present study, it is seen that CH improves the hardness of MTA. In future, MTA and CH can be used *in vivo* studies, and better clinical results can be obtained.

KEY WORDS: Calcium hydroxide, Endodontics, Mineral trioxide aggregate

INTRODUCTION

Mineral trioxide aggregate (MTA) is a mixture of three powder ingredients – Portland cement, bismuth oxide, and gypsum.[1] The principle compounds are tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite.[2] MTA consists of oxides and has fine hydrophilic particles which harden on contact with water. Hydration of the powder particles results in a colloidal gel that sets to a hard composition.[3] There are two types of MTA: gray and white.[4] It has been shown that both white and gray MTA has a similar chemical composition to Portland cement except for the addition of bismuth oxide to make it radiopaque.[5]

When MTA powder is mixed with water, calcium hydroxide (CH) and calcium silicate hydrate are initially formed and are eventually transformed into a poorly crystallized porous solid gel. The ratio of calcium silicate drops because of the formation of a calcium precipitate. The precipitated calcium produces CH, which is the cause of MTA's high alkalinity after hydration. Bismuth affects precipitation of CH after MTA hydration. As bismuth oxide dissolves in an acidic environment, it has been suggested that placing MTA in an acidic environment such as inflammatory tissues might result in the release of bismuth oxide. This might decrease MTA's biocompatibility because bismuth oxide does not encourage cell proliferation in cell culture. The amount of sulfur at the surface of set MTA is 3 times higher than the powder forms of MTA and that this layer protects the cement from further hydration and increased the cement's setting time.[6]

MTA is mixed with sterile water in a 3:1 powder to liquid ratio. The mean setting time of MTA is 165 ± 5 min, which is longer than amalgam, super EBA, and IRM. MTA's setting time and bacterial

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leakage are adversely influenced when the samples are kept in dry conditions.[6]

MTA when filled in root canal leaches is ions in the following order: calcium, silica, bismuth, iron, aluminum, and magnesium. Optical microscopic examination after resection of the root end revealed the presence of white layer between MTA and the root canal walls. This white layer composed of calcium, phosphorus, and oxygen similar to hydroxyapatite. Hydroxyapatite can release calcium and phosphorus required for bone metabolism which increases the sealing ability of MTA and promotes the regeneration and remineralization of hard tissues.[7]

MTA has been widely used for perforation repair, root-end fillings.[8,9] It is used in vital pulp therapy[10] and as an apical barrier for the treatment of immature teeth with non-vital pulps and open apices.[8] It also provides an effective seal against penetration of bacteria and their by-products. It has been recommended as a coronal plug after filling of the root canal system and as a temporary filling material.[11]

The various properties of MTA are:

- Solubility

The solubility of solid material is defined as the amount of substance that can be dissolved in a given amount of solvent. The powder to water ratio might influence the amount of solubility. Increasing the water powder ratio increases the MTA solubility and porosity. The addition of bismuth oxide makes MTA as insoluble.[7] Compressive strength the compressive strength is significantly less than amalgam, IRM and super EBA after 24 h. However, there is no difference in the compressive strength after 3 weeks. When blood gets incorporated into MTA, the compressive strength of the material is reduced. At the microstructure level, blood contamination of MTA resulted in a lack of acicular crystals which is the cause for reduced compressive strength.[6] The compressive strength of WMTA is greater than that of GMTA.[7]

The presence of wet cotton pellets for 24 h after the placement of MTA increases the flexural strength, while it decreases the flexural strength if WMTA receives moisture from both sides for more than 72 h.[7]

- Fracture resistance

The teeth filled with MTA had significantly more resistance to fracture compared with those filled with CH. The resistance to fracture of MTA filled teeth is attributed to the TIMP-2 which inhibit collagen destruction.[6]

- Bioactivity

A material can be considered bioactive if it evokes a positive response from the host. Bioactive material will be able to induce the formation of bond between tissue and the material. An artificial material can bind to living bone by the formation of a bone-like apatite layer on its surface in the body environment or by biofunctionalization. It is found that apatite layer forms 5 h after immersion into a phosphate-containing solution and a uniform thickness of the apatite layer is formed in 7 days.[6] Apatite formation might play a role in the mineralization activity of WMTA while having a definite effect on biocompatibility as a layer for tissue attachment.[12]

MTA is a biocompatible material and has antibacterial properties. It has the ability to induce the release of bioactive dentin matrix proteins.[13] It has other advantages such as minimal toxicity and pulpal irritation, non-mutagenicity, increased levels of alkaline phosphatase, interleukin production, and cementum growth.[14-31] It is sealing, mineralizing, and dentinogenic properties make it preferred choice for numerous clinical applications.[32]

Although MTA has several advantages, it also has disadvantages. MTA has long setting time of 4 h. This may favor the solubility and/or disintegration or displacement form the retrograde cavity.[33] Its push-out bond strength is reduced in an acidic environment.[34] To overcome, these properties MTA is mixed with CH.

CH has been widely used as a pulp capping agent.[35] Because it helps in formation of tertiary dentin; thus, it protects the pulp from thermal and other insults.[36] CH is also used as an intracanal medicament because of its well-known antimicrobial activity, which is related to its high pH.[37] Other biological properties are tissue dissolving ability, inhibition of tooth resorption and induction of repair by hard tissue formation. Because of these properties, CH has been recommended for use in various clinical situations.[38]

The purpose of this study is to check whether there is any difference in the surface microhardness of MTA when mixed with CH.

MATERIALS AND METHODS

Thirty extracted, single-rooted human teeth which include mandibular single-rooted premolars, maxillary incisors, and canines were selected in the study. The teeth were stored in 0.5% chloramine-T previously. The teeth were sectioned horizontally perpendicular to the long axis of the tooth into slices with a thickness of 1.0 mm. A diamond disc was used to obtain slices. The lumen of the sliced teeth was instrumented with gates Glidden burs sizes 2–5 to achieve standardized diameter cavities of 1.5 mm.

The sliced teeth were divided into two groups; one group was filled only with MTA and another group

was filled with mineral trioxide and CH. Distilled water was added to 1 g of ProRoot MTA. The mixed material was then added incrementally into the lumens of the discs of one group. MTA was mixed with CH in equal proportions and was added to another group. Surfaces of the specimens were wet polished at room temperature using minimum hand pressure and Silicon Carbide based sandpapers of varying particle size to provide smooth surfaces for ease of indentation testing. The polished specimens were cleaned gently under light pressure distilled water to remove surface debris. To prevent dissolution or water sorption, the surfaces were dried gently by air spray.

Hardness was measured using Vickers microhardness testing machine. The specimens were placed on a platform with the surface under testing facing the diamond indenter, in the form of a right pyramid with a square base and an angle of 136° between opposite faces subjected to a load of 30 g. Five indentations adjacent to each other were made on the surface of each specimen. The surface of the material after removal of the load is measured using a microscope. The Vickers microhardness was calculated and hardness expressed as Vickers pyramid number (HV).

RESULTS

The result is summarized in Table 1. Group I showed hardness of 54.7 ± 4.53 (HV) and Group II showed hardness of 55.2 ± 5.07 (HV). Group II showed higher hardness value than Group I and the mean difference between Groups I and II is statistically significant ($P < 0.05$).

DISCUSSION

The microhardness of MTA was influenced by factors such as thickness of material, condensation pressure, and pH.[39-42] In this study, the effect of CH on the surface hardness was evaluated, literature says that if the thickness of the MTA increases microhardness will also increase, i.e., thickness of material is directly proportional to microhardness.[43]

The properties of MTA are predominantly influenced by alkaline pH.[42] The effect of alkaline pH on microhardness of MTA showed increased micro-hardness as well as decreased porosities.[44,45]

Table 1: Vickers pyramid number for the experimental groups

Group	*n*	Mean±SD (HV)	*P* value
Group-I mineral trioxide aggregate	30	54.7±4.53	<0.05
Group-II mineral trioxide aggregate and calcium hydroxide	30	56.2±5.07	

SD: Confidence interval

The decrease in porosities will definitely increase the hardness of MTA.[46] In this study, we evaluated the hardness of MTA when mixed with CH. CH has a pH 11–12 (alkaline pH). Since CH has an alkaline pH, we assumed that microhardness of MTA will be increased when it is mixed with CH. Scanning electron microscope studies show that development of porous surface and lack of needle-like crystals in more acidic solutions, which may result in reduction of microhardness.[46] Leakage study reported that the time needed for leakage to occur was significantly higher when samples are stored in acidic pH than in alkaline pH.[47]

The particle size of a particular material will also have a significant role in micro-hardness. It was shown that smaller particle size and increased surface area of WMTA showed better chemical and physical properties because of rapid and more hydration with lower porosity.[48,49] Thus, it increases the micro-hardness of MTA.

MTA has better sealing ability than conventional materials such as amalgam, zinc oxide eugenol, and conventional glass ionomer when used as a root-end restoration, furcation, and apexification.[50] Literature showed that when MTA mixed with 10% calcium chloride showed a better sealing ability.[51] In this study, MTA is mixed with CH and checked for micro-hardness. In future studies, sealing ability of MTA mixed with CH should be evaluated.

Micro-hardness of a material is not influenced by a single property. It is influenced by other properties such as yield strength, tensile strength, and modulus of elasticity.[52] Micro-hardness indicates the setting process and overall strength or resistance to deformation.

Studies show that when calcium chloride when mixed with MTA has accelerated setting time.[53] Calcium chloride has no effects on handling characteristics. In the first 24 h after mixing MTA with calcium chloride, there is a significant increase in calcium release.[54] Furthermore, it has been confirmed that high amounts of calcium in a cell culture environment might downregulate cell proliferation.[55] The study also shows that >2% of $CaCl_2$ adversely affects the cement by increasing the risk of drying shrinkage and reducing the ultimate tensile strength.[56]

Condensation pressure also influences the micro-hardness of MTA. Based on findings of a study, it is seen that when greater pressures are applied to MTA during placement, is hardness is decreased significantly.[57] In a study it was indicated that greater condensation pressure would result in increase in hardness. Then, it showed that when the pressure was more than 3.22 MPa, surface hardness was reduced.

Specimens prepared with lower condensation pressure had more typical crystalline structures around the micro-channels. This leads to greater degree hydration of leading to well-formed crystalline structures.[57] Thus higher condensation pressure may pack the powder molecules close together resulting in reduction crystalline formation due to lack of sufficient space for water molecules which ultimately results in reduced hardness.

CONCLUSION

Mixing CH with MTA can improve its properties. In the present study, it is seen that CH improves the hardness of MTA. Previous studies show that CH can improve hardness, decrease the setting time, and increase the bond strength of MTA. Increasing the bond strength of MTA makes it possible to be used as a root-end filling material. Using CH also has some limitations. It has been reported that long-term treatment with calcium may weaken roots and contributes to fracture. In future, MTA and CH can be used in *in vivo* studies, and better clinical results can be obtained.

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