

Effect of temperature on the setting time of Mineral Trioxide Aggregate (MTA)

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Received: May 24th, 2015 – Accepted: July 27th, 2015

Abstract

Introduction: Mineral trioxide aggregate (MTA) has numerous applications in dentistry due to various advantages. However, its long setting time has still remained a problem. The current study was conducted to investigate the effect of temperature (ambient and distilled water temperature) on the setting time of mineral trioxide aggregate (MTA).

Materials and methods: This experimental study comprised of two parts. In the first part, MTA and distilled water samples were kept at ambient temperature for 24 hours (before mixing: effect of distilled water temperature on the setting time of MTA and after mixing: effect of distilled water and ambient temperature on the setting time of MTA), and analyzed and divided into three groups: group 1 (4°C), group 2 (37°C) and group 3 (90°C). The mixed samples were placed in the glass cylinders with an internal diameter of 8 mm and a height of 10 mm, and kept at 37°C temperature and 100% humidity. In the second part, the samples were prepared the same as those of the first part and divided into three groups according to the terms of maintenance: group 1 (4°C), group 2 (37°C) and group 3 (75°C). The mixed samples were then put in glass cylinders with an internal diameter of 8 mm and a height of 10 mm and the samples of groups 1, 2 and 3 were kept at 4, 37 and 75 °C, respectively. At the end of each part, the primary and final setting times were measured by Gilmore needle. Data were analyzed by SPSS using Kruskal-Wallis test ($p < 0.05$).

Results: The findings of this study showed a significant reduction of the primary and final setting time of MTA for the samples of both parts of the study with an increase in ambient temperature ($p < 0.05$).

Conclusion: This study indicated that increased ambient temperature caused a reduction in the setting time of MTA.

Keywords: Mineral Trioxide Aggregate (MTA), setting time, temperature

Introduction

Mineral trioxide aggregate (MTA) was first introduced in dentistry in 1993 as a filling material for the root apex. MTA has also been recommended for the pulp capping, pulpotomy, blocking the pores in the teeth with open apex, restoration of root perforations and canal filling [1].

MTA was first presented as derivatives of calcium oxide, silicate dioxide, and aluminum oxide that are converted to calcium silicate, dicalcium silicate and tricalcium aluminate compounds. Later, it was found that MTA, in addition to having bismuth oxide radiopaque factor, is very much similar to Portland cement. Depending on the type of commercial product, MTA compounds are different and are composed of 75% Portland cement, 20% bismuth oxide and 5% calcium sulfate dihydrate (Dentsply Tulsa) or 80% Portland cement and 20% bismuth oxide (MTA Angelus) [2].

Moreover, MTA contains slight amounts of SiO_2 , CaO , MgO , Al_2O_3 , K_2SO_4 and Na_2SO_4 [3,4]. Studies have shown that MTA and Portland cement have similar

antimicrobial activities [6] and biocompatibility [7] in some properties such as the improvement of periapical lesions [5]. MTA is available in white and grey forms. The white type, which is aesthetically superior, lacks tetracalcium aluminoferrite. The color difference is mainly due to lower amount of iron oxide in white MTA. The grey type of MTA is not usually used in cases where beauty is concerned [4].

Clinically, MTA has numerous advantages such as high sealing potential [8,9] good biocompatibility [10,11], acceleration of the amelioration of periapical lesions [12,13] and halting root inflammatory resorption [14]. In addition, the setting time of MTA is not influenced by the unfavorable effect of humidity or blood [15]. Although MTA is preferred in many dental treatments due to its numerous advantages, it has some deficiencies, including the handling problem and the long setting time [16]. Studies have shown that the setting time of MTA is longer than the common canal fillings such as amalgam, super-EBA, Intermediate Restorative Material (IRM) [17] and biodentine [18]. The longer setting time of root canal fillings is an unfavorable property because it facilitates

cement leakage in periapical procedures [19]. Clinically, some conditions like reverse filling and sealing perforation require a faster setting time in order to prevent dissolution of the components of the filling material by blood or tissue fluids [20]. As a generally accepted advantage, canal filling materials need to be immediately hardened after the insertion into the canal cavity to minimize the contact time of the filling material with vital tissues [18].

Various studies have been conducted to overcome the longer setting time of MTA. Lee et al. reported that although adding hydration accelerators such as citric acid, lactic acid, sodium chloride, and calcium lactate gluconate improves the setting time, it reduces the compressive strength during the mixing stage of MTA [21]. AIAenzi et al. showed that adding KY, CaCl₂ or NaOC₁ liquids to grey MTA improves the handling properties and reduces the setting time [22]. Recently, an attempt has been made to replace MTA by a calcium aluminosilicate cement called Quick-Set with a faster setting time. Although this material was similar to MTA in many restorative properties of periapical tissues, it resulted in more inflammation [23].

Aesthetically, white MTA is superior to the grey MTA [4] but the setting time of white MTA is longer than that of the grey type [1]. Further studies are needed to analyze the long setting time of MTA, especially the white type. This study investigated the effect of ambient temperature on the setting time of commercial white MTA.

Materials and methods

In this experimental study, white MTA (Angelus, Brazil) was used. The effect of temperature was evaluated in two Parts.

In the first part, 9 packages of MTA (each containing 0.5 gr MTA) and 9 distilled water ampoules (5 ml) were divided into three groups (n=3) according to the ambient temperature:

- group one at 4°C (in refrigerator for 24 hours)
- group two at 37°C (in incubator for 24 hours)
- group three at 90°C (in incubator for 24 hours)

The samples were immediately mixed with 3/ 1 proportion (MTA powder to distilled water) according to the manufacturer's instruction. The mixed materials were placed in glass cylinders (8 mm internal diameter and 10 mm height) and kept in incubator at 37°C and 100% humidity.

In the second part, the samples were prepared similarly to those of the first part and divided into three groups based on the maintenance conditions:

- group one at 4°C (in refrigerator for 24 hours)
- group two at 37°C (in incubator for 24 hours)
- group three at 75°C (in incubator for 24 hours)

Then, the samples were immediately mixed with 3/ 1 proportion (MTA powder to distilled water) according to the manufacturer's instruction. The mixed materials were poured in glass cylinders (8 mm internal diameter

and 10 mm height) and the samples of group 1, 2 and 3 were kept at 4, 37 and 75 °C, respectively under 100% humidity.

At the end of each part, the setting time of samples was measured by Gilmore needle according to similar studies [24-27]. Gilmore needle is composed of a metal frame on which two vertical axes are installed. A weight, to the end of which a needle with a specified diameter is attached, is installed on each of these vertical axes. A thin needle (415.6 gr) is attached to the bigger weight and a thick needle (2.12 mm in diameter) is attached to the smaller weight. The samples were tested at intervals of 1 or 5 minutes.

The primary and final setting times were respectively considered the times that the tip of light and heavy weights did not have an observable effect on MTA surface. The setting time of each sample was recorded. The obtained data were analyzed by SPSS software using Kruskal-Wallis test. P<0.05 was considered significant.

Results

The setting time of MTA was analyzed by two primary and final needles at different temperatures in incubator and sterile liquid. As reported in **Table 1**, in the primary needle test, the temperature of 4°C indicated the highest mean value for the setting time of MTA and the temperature of 75°C showed the lowest setting time with the mean time of 20 minutes. Based on the results of Kruskal-Wallis test, this difference was reported to be significant (p<0.023). As for the final needle test, the temperature of 4°C with the mean time of 87 showed the highest mean value for the setting time of MTA and temperature of 75°C indicated the lowest mean value for the setting time of MTA. To analyze and confirm the difference between the effects of different temperatures on the setting time of MTA, Kruskal-Wallis test was run and the findings showed a significant difference between temperatures (p<0.025).

Table 1 presents the number, mean values, and standard deviation of the setting time of MTA at different temperatures in incubator. According to **Table 2**, in the primary needle, the maximum mean setting time was reported for 4°C with the mean time of 43 minutes. Also, the minimum mean setting time was reported for 90°C with the mean time of 20 minutes. The results of Kruskal-Wallis test revealed that this difference was statistically significant (p<0.02). In the final needle test, the maximum mean setting time was observed at the temperature of 4°C with the mean time of 93 minutes. Further, the minimum mean setting time in the final needle test was reported for the temperature of 90°C with the mean time of 38 minutes. The findings of Kruskal-Wallis test showed this difference to be statistically significant (p<0.023). **Tables 2-1** show the number, mean value, and standard deviation of the setting time of MTA at different temperatures of sterile liquid.

Table 1. Number, mean value, and standard deviation for the setting time of MTA at different temperatures in incubator

Temperature	Primary needle			Final needle		
	Number	Mean	SD	Number	Mean	SD
4°C	3	42	3	3	87	3
37°C	3	27	3	3	47	3
75°C	3	20	0	3	37	3

Table 2. Number, mean value, and standard deviation for the setting time of MTA

Temperature	Primary needle			Final needle		
	Number	Mean	SD	Number	Mean	SD
4°C	3	43	3	3	93	3
37°C	3	35	3	3	75	0
90°C	3	20	0	3	38	3

Discussion

One of the major problems of MTA is its long setting time. The current study investigated the effect of ambient temperature on the setting time of MTA. The results indicated a difference in the setting time at different temperatures. The results of the primary and final needle tests in incubator indicated that the minimum and maximum setting times of MTA were reported for the samples kept at temperatures of 4 and 75 °C, respectively. However, similar results were obtained for distilled water at different temperatures. These findings demonstrate that temperature can affect the setting time of MTA and the setting time reduces with a rise in temperature.

To confirm the effect of ambient temperature on MTA properties, Saghiri et al. showed that temperature could influence the surface hardness and the microscopic structure of MTA [24]. The effect of temperature on the setting time of MTA can be attributed to the chemical processes of the main material of MTA, Portland cement. Portland cement is hardened in contact with water; this is when a chemical reaction occurs between water and cement [28]. It has been shown that the size of particles [29], proportion of powder to liquid [30], presence of air in

the mixture [31] and ambient temperature [32,33] can affect the physical properties, hydration process and synthesis of Portland cement. The hydration of MTA produces calcium hydroxide and hydrate silicate calcium (H-S-C) gel. H-S-C gel results in cement resistance, thereby contributing to the stability of hydrated cement [34]. According to the research, the hydration of Portland cement reacts to temperature and this reaction is pyrogenic [35,36].

In the present study, the setting time of MTA varied from 37 to 93 minutes depending on the ambient temperature or distilled water temperature. In previous studies, different setting times have been reported for the white MTA (ProRoot MTA), 165 ± 5 minutes [23], 170 ± 2 minutes [37] and 228.33 ± 2.88 [18], which are higher than those of the present study. Other studies have also reported a longer setting time for MTA than that of the current study [38-43], which can be due to the conditions of using distilled water regardless of temperature.

Conclusion

The results of this study showed that ambient temperature before and after mixing has a significant impact on the setting time of MTA and the increased ambient temperature reduces the setting time.

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