Effect of anti-expansion solution on setting expansion and setting time of dental plaster

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Abstract

A study was performed to evaluate the effect of anti-expansion solution on setting expansion and setting time of dental plaster. Test solution (6% anti-expansion solution composed of 6% potassium sulphate and 0.6% borax) was prepared with water at room temperature. Dental plaster (Hnin Peral, Myanmar) was mixed with ordinary tap water or test solution in the water powder ratio of 0.45 at room temperature and poured on the mounting plate of the mean valued articulator (Proarc IG, Shofu, Japan) in a size of 48 mm in diameter and 45 mm in height. Vertical dimension change was measured on the articulator between two points; one on the movable arm and the other on the base by using digital slide caliper after 1, 2 and 24 hr. Student's t test was employed to analyze the results. Vertical dimension changes of control and test groups after 2 hr were 0.65 mm and 0.15mm respectively which was statistically significant ($p<0.001$). Setting time with anti-expansion solution was also significantly less than control. It was concluded that tested anti-expansion solution accelerates the setting time easing the handling of the mounting casts and reduces the setting expansion of plaster, effectively reducing vertical dimension change and preventing the laboratory errors.

Introduction

Every indirect dental prosthesis is fabricated separately in the dental laboratory after taking impression from the patient, and creating dental casts. These laboratory works need to be performed carefully in each and every step of the process. Otherwise each tiny procedural error will accumulate resulting in serious errors in the end products which will lead to many problems in the clinical side. Dental prostheses are fabricated indirectly on the casts and die made from gypsum products. These gypsum products are made from calcination of the gypsum and the main constituent of the gypsum derived products is the calcium sulfate hemihydrate.1, 2, 3 Depending on the method of calcination, different types of gypsum products can be produced with different strength and these various types require different amount of water during mixing. This is due to the difference in size and density of the containing particles, (spongy , irregular shaped beta-hemihydrate in Plaster of Paris or dense, prismatic shaped alpha-hemihydrate in dental stone).[1] The gypsum products can be divided into type I: Impression plaster or mounting plaster, type II: Model plaster, Type III: Dental stone, Type IV: Dental stone (high strength, low expansion), Type V: Dental stone (high strength, high expansion).[3] Most of the indirect prosthetic restorations require laboratory works where the recorded patient's dental casts are mounted on the articulator along with the bite registration. Since mounting plaster is not available in Myanmar, type II Paster of Paris (POP) is being used to mount the casts on the articulator prior to fabricate dental prostheses. As a result, setting expansion & longer setting time results in changing of vertical dimension of the mounted articulator leading to alteration of occlusal planes, prolonged chair-side time or even serious errors in worse cases. Thus, controlling the setting expansion of plaster with the anti-expansion solution (AE) is crucial to lessen those unwanted procedural errors.

This study was aimed to evaluate the effect of the custom-formulated anti-expansion solution containing potassium sulphate and borax in various proportions on the setting expansion and setting time of Plaster of Paris.

Materials and methods

(1) Plaster of Paris (Hnin Pearl)- 150g

(2) Potassium sulphate- 4.05g
(3) Borax- 0.4g
(4) Tap water- 67.5ml

Tested anti-expansion solution is made by mixing potassium sulfate and borax in a tap water at room temperature. Water powder ratio of 0.45 is used. Dental plaster is mixed with ordinary tap water and tested solution according to the water powder ratio. Then it was poured on the mounting plate of a mean valued articulator (Proarc IG, Shofu, Japan) in a size of 48mm diameter and 45 mm in height. In order to measure vertical dimensional changes due to setting expansion, two points were marked on the articulator, one on the movable arm and another on the base. After that the changes between the two points were measured by using a digital slide caliper after 1hr, 2hrs and 24 hrs.

Student's t test was employed to analyze the results. To measure the setting time, a laboratory thermometer was put into the POP filled mold next to stop watch and video record was made to record the rise and fall of the temperature.

Figure 1. Experimental design for measuring plaster expansion (upper panel) and measurement of setting time through temperature change recording (lower panel)

Results

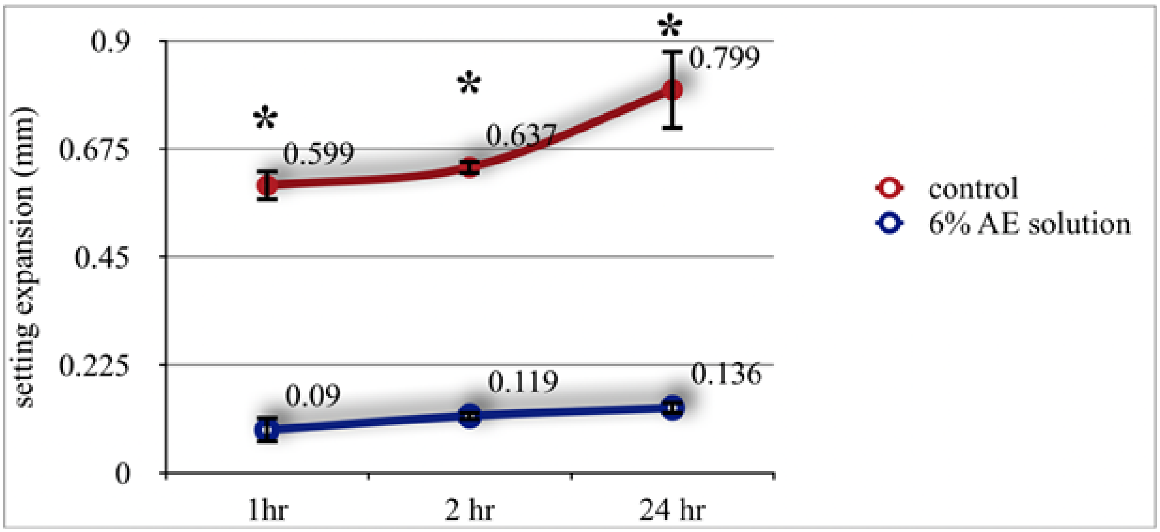

Figure 2. Comparison of setting expansion of plaster mixed with tap water and one with tested solution (* $p<0.05$)

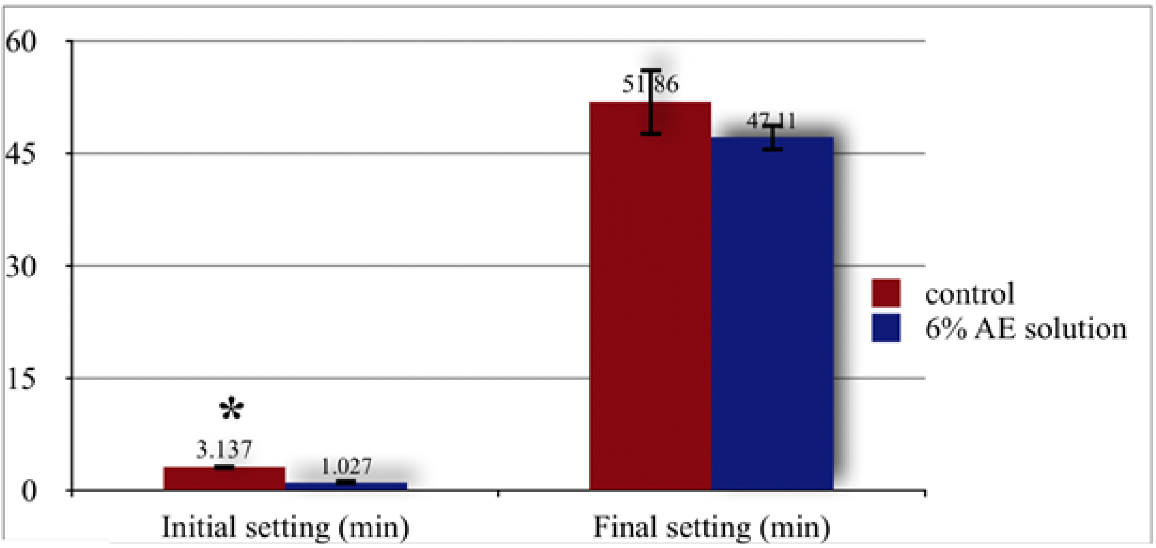

Figure 3. Comparison of setting time of plaster mixed with with tap water and one with tested solution (* $p<0.05$)

There was significantly higher setting expansion of plaster of the control than tested one with anti-expansion solution ($p<0.05$). Moreover, the tested anti-expansion solution significantly accelerated the setting time (esp; initial setting) ($p<0.05$) easing the handling of the mounting cast and minimizing lab errors.

Discussion

In this study, the effect of anti-expansion on the setting expansion and setting time of Plaster of Paris was evaluated. Two different nature of the setting Plaster of Paris (POP) were examined; the setting expansion and the setting time. Regarding the setting expansion, Plaster of Paris is formed by calcination of the gypsum which is the dehydration of the gypsum material. The resulting product contains calcium sulfate hemihydrate particles. When mixing the POP with water, the entire process is reversed. The hemihydrate dissolves in the solution and dihydrate crystals precipitate as the setting reaction occurs. During the setting reaction, the unwanted phenomenon called setting expansion occurs [1,2]. The setting POP expresses expansion due to the nature of the crystal growth of the precipitating dihydrate crystals [4]. The growing crystals have spherulites which are radiating arrays from the center of the growing crystal.

During the growth of the crystals, those spherulites from one crystal make more contact with those from the neighboring crystals and they produce a small force. These dynamic forces become significant when a large number of crystals in the setting plaster are taken into account and called crystal growth pressure [1]. There are other factors which influence the setting expansion of the plaster such as the mixing time and water-powder ratio. The mixing time of the POP with water has effect on the setting expansion in the same way as the nature of the growing crystals. Because speculation of the plaster can break up the forming dihydrate crystals in the mix and this will increase the number of the nuclei of crystallization. Thus, the longer the mixing time is, the greater the setting expansion will be. And water-powder ratio is also a crucial factor in the control of the setting expansion [5]. Regardless of the hunch of the plaster becoming more expanded if more water is used, the reality is the inverses. If a high water-powder ratio is used, the number of crystals in a unit volume is reduced. And if lower water-powder ratio is used, the density of the crystal in a unit volume will be high in a thicker mix[2]. Thus more outward thrust of the crystal growth pressure will occur more in a lower water-powder ratio. These factors are the basics which influence the setting expansion of the dental plaster which will further alter the dental laboratory procedure and leading to the procedural error.

In Myanmar, Type I mounting plaster is not available and instead the model plaster or type II plaster is being used for cast mounting procedure on an articulator. The setting expansion of this type II plaster can lead to the errors in the mounting procedure by altering the vertical dimension of the mounted casts. This error can lead to alteration of the occlusal plane of the prosthesis, increasing the clinical chair side time and could even cause fatal error for those people who are doing research on the jaw relation or those research which would involve the mounting on an articulator. According to the results, the formulated anti-expansion solution resulted in less expansion of plaster. Potassium sulphate can reduce the setting expansion by reduction of the axial ratio of the growing needle like arrays of the crystals. But its drawback is that potassium sulphate can not only reduce the setting expansion but also accelerate the setting reaction. This acceleration of the reaction rate is due to increased rate of hemi-hydrate dissolution [6]. Some research tried to reduce the setting expansion by adding additive to the power. But the expansion reduction result is not much [7].

Thus, potassium sulphate alone will cause inadequate working time and a retarder is needed to use it practically. Borax which is a retarder is used in combination to apply it practically. Theoretically, 4% potassium sulphate and 0.4% borax is used in anti-expansion [1,5]. In this research, after running trial sample with different concentration, the 6% potassium sulphate and 0.6% borax can reduce the setting expansion of the local Plaster of Paris products most efficiently. In order to eliminate the variation due to various factors affecting the setting expansion, water-powder ratio of 0.45 was used. If the water-powder ratio is too low, the setting time of the model with anti-expansion is too quick that the model cannot be mounted systematically. On the other hand, if the water-powder ratio is too high the expansion of the control model is too low to measure and too much flow of plaster complicated accurate mounting. Thus, the intermediate water-powder ratio was selected after multiple tests. Another variable factor is the mixing time. Theoretically, the more the mixing time is the more the setting expansion of the plaster. Moreover, mixing of the plaster with tested solution did not allow too much time for mixing due to quick setting. Thus, mixing time of 30 seconds was used for every research model.

The second one to discuss about is the setting time of the dental plaster. Setting time is the term used to determine a certain period when the plaster can be operable without significant changes to the structure. The setting time is usually measured by Gillmore needle. But this measurement only describes the time at which certain strength is achieved because the setting reaction may or may not completed yet [1]. For example, if the fabricated model is too porous or weak, the necessary strength which can resist the Gillmore needle may not be achieved at all. Thus, in this research, a different approach was used to measure the setting time through the setting reaction. Because the setting of the Plaster of Paris is exothermic [3], a laboratory thermometer was inserted into the dental plaster placed next to a stop watch and a video record was made to record the time at which initial rise in temperature or the time at which the final temperature was reached. The final temperature was usually below the starting temperature of the dental plaster before the rise. As shown in the result, the tested solution had statistically significant effect on the reduction of initial setting time compared to the control blocks. This quick setting can reduce the time in which various errors can occur in the articulated cast mounting.

Conclusion

Tested anti-expansion solution reduces the setting time and setting expansion of the plaster minimizing unwanted dimensional changes. It may be applicable in formulating anti-expansion solution for mounting plaster.

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