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Effect of Incorporation of Disinfectant Solutions on Setting Time, Linear Dimensional Stability, and Detail Reproduction in Dental Stone Casts

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Abstract

Purpose: The aim of this paper was to analyze the influence of incorporation of disinfectants during the cast die stone-setting time. Setting time, linear dimensional stability, and reproduction details on casts were measured.
Materials and Methods: Die stone type IV specimens with disinfection solutions (sodium hypochlorite 1%, glutaraldehyde 2%, chlorhexidine 2%) were incorporated in two concentrations (50%, 100%). The detail reproduction, dimensional stability, and setting time were tested in accordance with ADA recommendations.
Results: Disinfecting solutions promoted an increase in setting time compared to control; sodium hypochlorite was responsible for the highest setting time. The addition of undiluted sodium hypochlorite 1.0% led to contraction during setting, but the groups with 50% diluted sodium hypochlorite 1.0% and undiluted chlorhexidine 2.0% resulted in intermediate values compared to the other groups, thus matching the control. The others did not demonstrate any effect on expansion. For detail reproduction, it was observed that the control group presented results similar to the others, except those where sodium hypochlorite was added.
Conclusions The addition of sodium hypochlorite in both dilutions significantly altered, negatively, all the evaluated properties. But the addition of glutaraldehyde and chlorhexidine did not promote any significant alterations in the evaluated properties.

In dentistry, there is an enormous exposure to pathogenic microorganisms in saliva and blood. Therefore, the ADA recommends that dentists and their assistants wear gloves, masks, and ocular protectors to protect patients and themselves from these potentially transmissible contaminants.[1]

In prosthodontics, direct physical involvement between dental offices and laboratories is inherent to the manufacturing of prosthetics. Such proximity has been a cause of concern for regulatory agencies. In 1996, the ADA along with the National Association of Dental Laboratories of the United States (NADL) formulated “Infection Control Recommendations for the Dental Office and Dental Laboratory,” which for the first time included recommendations for the commercial laboratory as well as the dental office.[2] The disinfection of casts became an important procedure for obtaining noncontaminated models, in view of the potential transference of infectious agents of the blood or the saliva situated in the molds for the casts, thus establishing a cross-contamination control procedure as observed by Leung and Schonfeld.[3]

The disinfection of plaster models can be carried out through spraying or immersion in a disinfecting solution[4,5] and the incorporation of antimicrobial agents in the plaster mass;[5,6] however, immersion of casts has been related by some authors as being deleterious to the final quality of the cast,[6] as spraying them with disinfecting solutions has not presented any harmful effects to the surfaces of the plaster casts.[7] However, due to the porosity of plaster, spraying may not disinfect the whole surface of the cast efficiently.

Since the disinfection process must be effective without causing alterations on the final quality of the casts, the incorporation of disinfecting solutions in plaster has been regarded as a promising alternative. The aim of this paper was to analyze the influence of incorporation of disinfectants during the cast die stone-setting time. Setting time, linear dimensional stability, and reproduction details on casts were measured.

Materials and methods

This study was carried out in accordance with ADA Specification No. 25,[8] which states that research related to gypsum products is to be conducted in environments with temperature at 25°C (±2°C) and relative humidity at 50% (±10%). With respect to such parameters, the research was then conducted with the following groups of specimens:

Group 1– gypsum mixed as per the recommendations of the manufacturer (control);
Group 2– substitution of 100% of the water for sodium hypochlorite 1.00%;
Group 3– substitution of 50% of the water for sodium hypochlorite 1.00%;
Group 4– substitution of 100% of the water for glutaraldehyde 2.00%;
Group 5– substitution of 50% of the water for glutaraldehyde 2.00%;
Group 6– substitution of 100% of the water for chlorhexidine gluconate 2.00%;
Group 7– substitution of 50% of the water for chlorhexidine gluconate 2.00%.

Setting time

Setting time was determined through already established methodology,[8] which recommends the use of a Vicat apparatus, which allows the analysis of the setting time through the insertion of a metallic needle (1 mm diameter, 50 mm length) connected to a vertically mobile aluminum rod, under a total weight of 300 g. A ring of PVC with an internal diameter and height of 25 mm was attached to a circular glass plate and placed at the base of the Vicat apparatus. The plaster mass was shed into the ring, with the aid of a vibrator (VH Softline, VH Medical Equipment and Accessories Ltda, Araraquara, Brazil), for the gauging of the setting time.

The needle was then placed at a distance of 0.5 mm from the gypsum surface (Fig 1), and abruptly set free 2 minutes before the mass lost its superficial shine, thus allowing the complete insertion of the needle. After this, sequential insertions were carried out every 15 seconds in different areas (standardized in quadrants), until the needle could not fully penetrate the mass any longer.[9] The time spent between the beginning of the mixing up to the point where the needle could not fully penetrate the mass any longer was measured with a chronometer (C 510, Oregon Scientific, Portland, OR), and thus the Vicat setting time was obtained.[8,10]

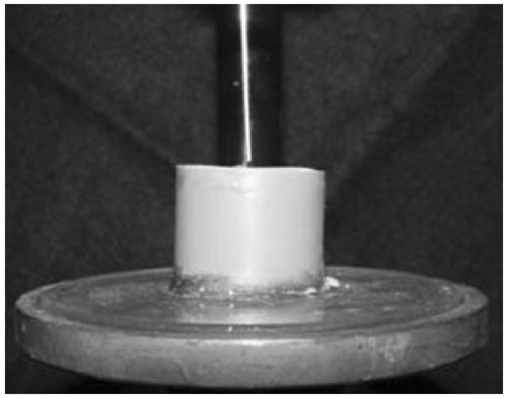

Figure 1 Initial needle position for the setting-time test.

Dimensional stability

A device described by Ferreira et al[11] was used in the study of the dimensional stability of the previously mentioned plaster. The device consists of a digital centesimal-precision dial comparator (Mitutoyo, Absolute, Mitutoyo, Aurora, IL) connected to a base that allows vertical placement, with the analytical tip of the dial being the only moving part during the gauging.

A flexible rubber ring was used to avoid restricting the expansion of the gypsum that was fixated with polyvinyl acetate-based glue in a glass plate. Plaster was manipulated according to the recommendations of the manufacturer, and the mass was then shed under vibration into the rubber ring. After the initial setting time,[11] a glass plate was placed on the surface of the gypsum, and the specimen was positioned for measurement (Fig 2). After 2 hours, the specimens were removed from inside the rubber ring and measured with an electronic caliper (Mitutoyo), thus obtaining their final length.

The final length value (L_f) of the specimens, along with the length alteration (ΔL) in mm after 2 hours, allows the calculation of the initial length (L_0), and, with this, the alteration

Figure 2 Dial comparator position for measurement of dimensional stability.

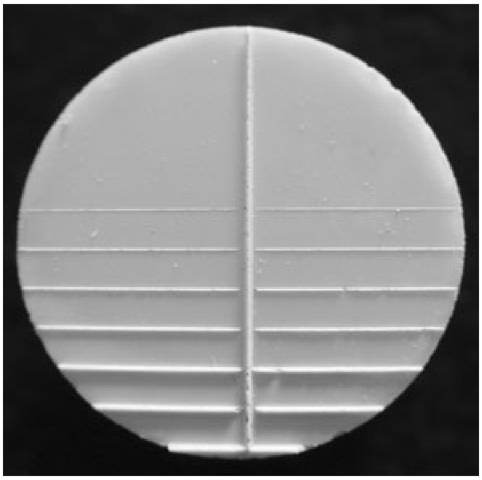

Figure 3 Reproduction of stainless steel plate in the test of detail reproduction.

in linear dimension in percentage (% ADL) according to the following formulas:

$$L_0 = L_f - \Delta L\%$$

$$ADL = \Delta L / L_0 \times 100.$$

Reproduction details

For the analysis of the reproductive capacity of plaster, a stainless steel plate was produced with lines indicating different depths varying from 0.025 to 0.300 mm, respecting the norms established by ADA Specification No. 25.[8] On the metallic plate, a ring with 30 mm diameter and 15 mm height was fixed, so that the 0.050 mm depth line remained centered on the ring. After the plaster was mechanically mixed under vacuum with each sample solution, it was subsequently poured under vibration into the cylindrical ring. After 2 hours, the specimens were removed, and the surface was analyzed in a stereoscopic magnifying glass at 10×, with the aid of the Leica QWin image analysis system (Leica Microsystems Imaging Solutions Ltd., Cambridge, UK). A satisfactory reproduction of details was considered when the ring copied the 0.050 mm line continuously for the entire diameter (Fig 3). Detail reproduction was considered satisfactory when a copy of the 0.050 mm line appeared along the whole diameter of the ring.

Results

Setting time

A significant statistical difference among the seven groups ($I = 49.4151$; $p = 0.000$) was evidenced by means of the Kruskal–Wallis test. Nonparametric, multiple comparisons followed. Figure 4 contains the results of this analysis, as well as the average levels of each group. The horizontal lines represent the results of the multiple comparisons, where groups under the same line are considered similar.

By means of the inferential analysis, it was observed that all the disinfecting solutions promoted an increase in the Vicat setting time, compared to control. The effect of the chlorhexidine was similar to the one observed for the glutaraldehyde; similar concentrations of both substances caused a similar behavior

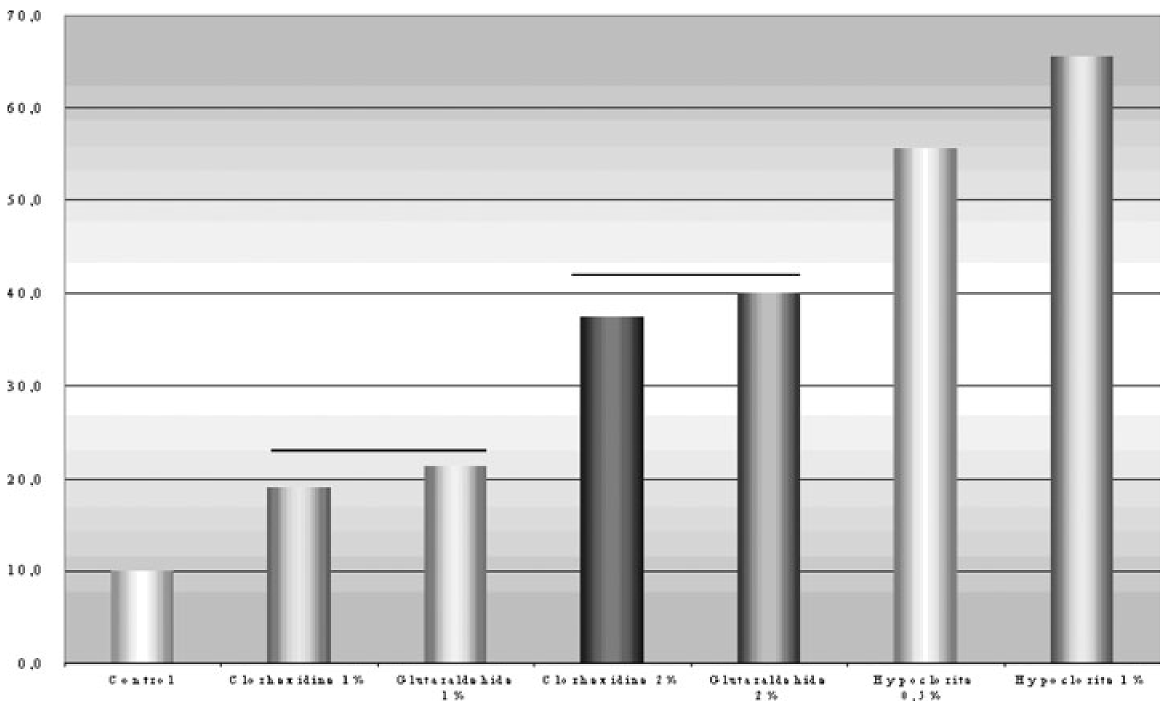

Figure 4 Levels of the assessed groups for the Vicat setting time. Y-axis: setting time (seconds).

Table 1 Average levels of the groups and results of nonparametric multiple comparisons for linear dimensional stability (same letters show similarity between groups)

Group	Mean		
Glutaraldehyde 1.0%	27.0	A	
Glutaraldehyde 2.0%	25.6	A	
Control	22.9	A	
Chlorhexidine 1.0%	22.9	A	
Chlorhexidine 2.0%	16.6	A	B
Sodium hypochlorite 0.5%	8.0	A	B
Sodium hypochlorite 1.0%	3.0		B

with the gypsum. Sodium hypochlorite was responsible for the highest setting time, as with the other disinfecting agents, the increase was proportional to the concentration.

Dimensional stability

A significant difference among the groups was found ($H = 25.989$, $p = 0.000$) by the Kruskal–Wallis test. Table 1 presents the results obtained for multiple comparisons. It is possible to observe that the addition of undiluted sodium hypochlorite 1.0% led to an alteration of the expansion characteristics during the setting time. Fifty-percent-diluted sodium hypochlorite 1.0% and undiluted chlorhexidine 2.0% groups resulted in intermediate values compared to the other groups, thus matching the control. The others did not demonstrate any effect on expansion.

Detail reproduction

The results obtained for detail reproduction are shown in Figure 5, in percentages. By means of the interpretation of reliability intervals, it is possible to observe that the control group presented results similar to the others, except those where sodium hypochlorite was added. Detail reproduction of the evaluated material was harmed by the incorporation of sodium hypochlorite, but not by the addition of other disinfecting agents.

Discussion

Setting time

The time interval between the beginning of the mixture of the gypsum powder to the liquid and the complete hardening of the material is defined as the setting time.[12] It is usually measured with some type of penetration test, using Gillmore needles for the initial (smaller needle) and final (longer needle) setting tests; however, following ADA Specification No. 25,[5] the setting time was obtained using a standardized Vicat apparatus.

Based on the results, it could be verified that all the disinfecting solutions in the evaluated concentrations promoted an increase in the Vicat setting time; however, the results obtained with the addition of glutaraldehyde and chlorhexidine, although statistically higher than the control group, are found to be within the limits established by the ISO,[10] which establishes a setting time for type IV plaster of 6 to 30 minutes.

The incorporation of sodium hypochlorite was responsible for the most substantial alteration in the setting time, with the

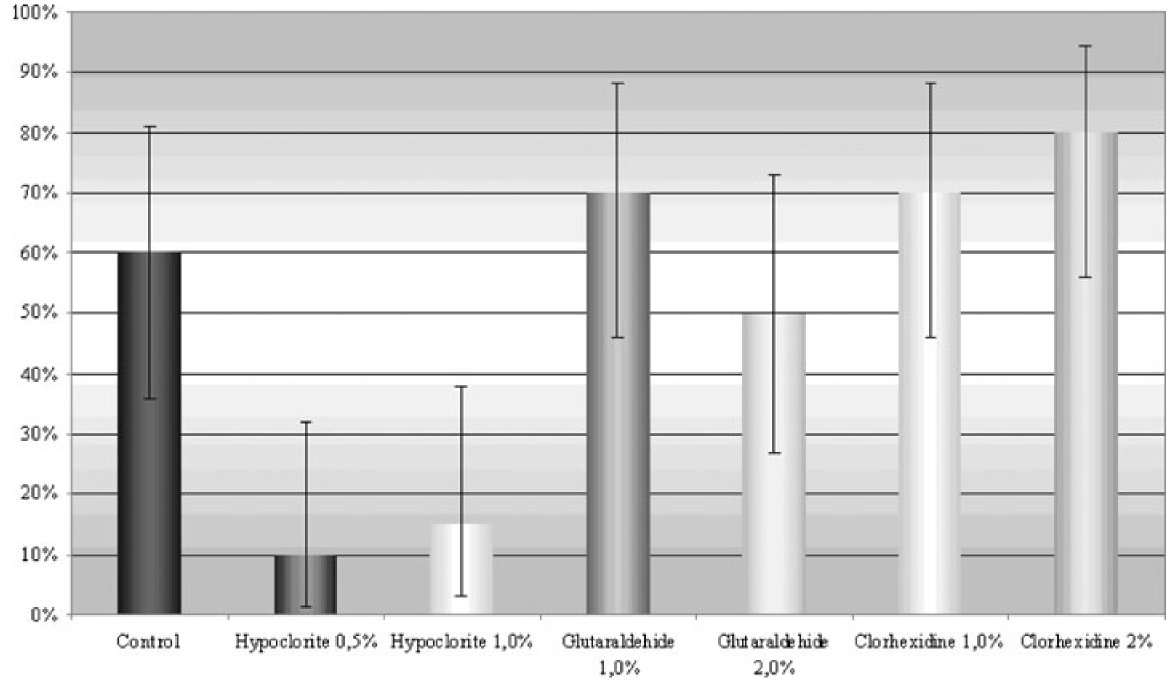

Figure 5 Percentage of success in detail reproduction. Y-axis: percentage of detail reproduction.

increase being proportional to the concentration. The evaluated time was outside the range of ISO standards,[10] similar to the results found by Donovan and Chee[13] and also by Ivanovski et al.[5]

Industrially, some chemical modifying agents are added to odontological plaster and may accelerate or delay the setting time. The rationale behind such behavior in these chemical agents has still not been completely elucidated, but it is known that low-solubility salts, such as sodium chloride and sodium sulfate in high concentrations delay the setting time. This occurs due to the setting-time process, where the amount of free water in the mixture diminishes and the concentration of the additive increases. When the solubility limit of salt is exceeded, it precipitates in the crystallization nucleus and poisons the mixture, modifying its normal conformation.[14]

Therefore, the substantial alteration provoked by the incorporation of sodium hypochlorite is supposedly due to the formation of a low-solubility salt that, when present in high concentrations, modifies the crystallization nucleus and consequently delays the setting time; however, Donovan and Chee[13] and Breault et al[12] obtained results opposite those achieved in this experiment, using a highly diluted concentration of sodium hypochlorite. That can be explained by the fact that some retardants act as accelerators when in low concentrations.[14] Nevertheless, this particular behavior in these chemical agents is not fully known, as previously mentioned by several authors.[5,13-15]

Dimensional stability

The expansion of the plaster mass during the hydration of calcium sulfate has been discussed[1,16,17] and, depending on the composition of the gypsum and the calcination process, a linear expansion varying between 0.06 and 0.5% of the total volume is expected.[14,15]

The dimensional stability of plaster is of ultimate importance in the odontological casts, since an exaggerated alteration on the surface of the casts would compromise the corresponding mold and would produce prosthetics of flawed quality. Therefore, the ideal disinfection of the odontological casts through the incorporation of disinfecting solutions should not promote alterations in the dimensional stability of plaster.

Thus, the obtained results allowed for the observation of statistically similar behavior between the control group and the plaster mass with added chlorhexidine or glutaraldehyde, indicating that these disinfecting solutions did not influence the expansion. On the other hand, sodium hypochlorite modified the characteristics of such expansion, leading to a contraction of the material during the setting.

According to Anusavice[15] and O'Brien,[14] the chemical agents that regulate the setting time of the gypsum products, in general, reduce the expansion that occurs during the hydration of calcium sulfate. Hence, manufacturers can simultaneously reduce the expansion and control the setting time with the controlled addition of accelerators and retardants. Based on this affirmation, an alteration of the dimensional stability under the addition of the sodium hypochlorite was expected, since it acts as a retardant in the assessment of the setting time.

Detail reproduction

Detail reproduction is an important characteristic of odontological plaster, since the correct adaptation of the prosthetic restoration is directly related to the exactitude of the cast.[18] As a result, the incorporation of disinfecting solutions should not interfere with the reproductive capacity of type IV gypsum.

By means of the interpretation of the data obtained in this study, it was possible to observe that the control group presented results similar to the remaining groups, except those with the incorporation of sodium hypochlorite, which in turn harmed the reproductive capacity.

The incorporation of sodium hypochlorite, as previously mentioned, is responsible for several alterations in the crystals formed during the plaster setting reaction, causing, according to Abdelaziz,[19] an increase in porosity of the casts. The increase in porosity is responsible for the weakening of plaster (reducing its resistance to compression and the diametrical traction)[5,20] and also harms the capacity of fine detail reproduction.[12]

Along with the increase in porosity, the addition of sodium hypochlorite affects dimensional stability, which in turn harms the detail reproduction of the gypsum.[11] With the results of dimensional stability obtained in this research, added to the increase in the porosity mentioned by some authors,[19] such detail reproduction behavior of the groups with incorporation of sodium hypochlorite was expected.

Conclusions

According to the methodology used in this study, we can conclude the following:

(1) the incorporation of chlorhexidine and glutaraldehyde in the concentrations and dilutions used in this study did not harm the detail reproduction capacity of gypsum;
(2) the linear dimensional stability of gypsum mixed with glutaraldehyde and chlorhexidine presented an expansion statistically similar to the control group;
(3) the setting time increased in all evaluated samples; however, glutaraldehyde 1% and chlorexhidine 1% obtained values within the ISO standards,[13] independent of the dilution; and
(4) sodium hypochlorite 1.0%, in both dilutions, caused severe alterations in all properties evaluated.

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