Effect of disinfectant agents on certain physical and mechanical properties of type IV dental stone

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ABSTRACT

Background: Dental stone casts come into contact with impression materials and becomes susceptible to cross contamination from saliva and blood. This study was done to evaluate the physical and mechanical properties of dental stone type IV after treatments with various disinfecting agents and regimes (methods).

Materials and Methods: Type IV dental stone and different types of disinfecting agents were used and divided into seven groups: **G1**: dental stone without disinfection (control group), **G2**: dental stone mixed with silver nitrate powder 0.5% , **G3**: dental stone mixed with silver nitrate powder 1%, **G4**: dental stone mixed with copper sulfate powder 0.5%, **G5**: dental stone mixed with copper sulfate powder 1% ,**G6**: dental stone immersed in propanol 70% and **G7**: dental stone immersed in ethanol 70%.Setting time, linear setting expansion, surface detail reproduction, compressive strength of type IV dental stone as well as compatibility with auto mixing addition silicone impression material were evaluated. The statistical analysis were conducted by ANOVA test followed by LSD test ($p<0.05$), also chi square test was used.

Results: The compressive strength, linear setting expansion, surface detail reproduction and compatibility of stone specimens was affected to a higher extent by mixing with silver nitrate powder 1%, copper sulfate powder 1% while treating the stone specimens with the disinfecting powders at low concentrations as well as immersion of stone specimens in either ethanol or propanol for 15 minutes produce less effect on the previous tested properties.

Conclusion: Silver nitrate 0.5%, copper sulfate 0.5% powders as well as 15 minutes immersion in 70% ethanol or 70% propanol did not promote adverse alterations in most of evaluated properties of type IV dental stone.

Key Words: Gypsum products, metallic disinfectants, ethanol, propanol. **(J Bagh Coll Dentistry 2014; 26(1):24-31).**

INTRODUCTION

The need for an infection control program is felt because a number of bacteria, fungi, and viruses present in the dental environment have been linked to debilitating and life-threatening diseases. Every effort, therefore, must be made to avoid cross contamination of these microorganisms and to prevent the potential transfer of disease in the dental setting. One common dental procedure that may cause cross contamination, especially between patients and dental laboratory personnel, is transfer of infectious agents from blood and saliva to the casts through impressions, record bases, occlusion rims, and trial dentures [1,2].

Gypsum products have been considered to be among the most widely used model and die materials. Modifications of these materials by adding chemicals or salts result in a change in their structure [2,3]. American Dental Association (ADA) and the Center for disease control and prevention (CDC) have suggested methods for the disinfection of dental casts including immersion in or spraying with a disinfectant [3] .Several studies have been attempted to come up with an improved system for models and die constructions [4], other studies attempted to improve the mechanical properties of gypsum products and oriented mainly towards the decrease of water requirement [5].

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In order to improve gypsum materials many attempts have been made by the use of various additives to gain several modification related to the chemical, mechanicals, physical and other properties of gypsum material [6,7] .

Chemical disinfectants can also be added directly to the dental stone [8,9]. However, adding disinfectant in dental stone, have been reported to compromise critical properties of the cast such as compressive strength, setting time and dimensional accuracy [10,11].

This study was done to develop a dental stone with disinfecting properties and still has adequate physical and mechanical properties.

MATERIALS AND METHODS

In this study type IV dental stone (elite stone, NAVY BLUE. Rovigo- Italy) was used. Ten specimens were prepared for each tested property following the water powder ratio recommended by the manufacturer instructions (powder water ratio 100gm/25ml). The dental stone was immediately poured in the molds with the aid of a mechanical vibrator, the stone specimens were separated from the molds 45 minutes after the starting of the mix and left to dry for 24 hours at (23±2)°c before testing. Two different disinfection methods (incorporation and 15 minutes immersion for the set gypsum specimens) were applied and four disinfectant agents were used 0.5% , 1% silver nitrate (SCRC, China: sinopharm chemical reagent company) ,0.5% , 1% copper sulphate (Barcelona, Espana), 70%propanol and

70% ethanol .The following physical and mechanical properties were evaluated for the prepared stone specimens:

1. **Setting time**

According to ADA specification no.25, metal ring (2.5 cm inside diameter and 2.5 cm high) was used to test the setting time of the disinfected stone specimens using apparatus with 1 ± 0.05 mm needle diameter and 240 g weight (B.S.12: part 2:1971). Standard mix of 200g powder and 50 ml distilled water according to manufacturers instruction was prepared and immediately transferred to the cylindrical mold painted with separating medium (SHANGHAI NEW CENTURY DENTAL MATERIAL CO.LTD) then the needle tip brings in contact with the surface of the tested material locking it in position with the thumb screw, the needle was released and allowed to penetrate the sample at 15 second intervals.

After each penetration the needle was cleaned and the mold moved to allow another penetration in a new area, the average value for two tests was measured as initial setting time, figure (1).

Figure 1: Vicat device for measuring the setting time of gypsum products

2. **Linear setting expansion**

To evaluate and compare linear setting expansion of conventional type IV dental stone (control group) and the experimental groups (disinfected specimens), 10 Stone specimens were prepared for the control and the experimental groups. Metallic model with of seven slots with widths ranging from 0.025 to 0.300 mm and 2.5 mm of distance between the grooves according to ADA specification No. 25 for dental gypsum products was used [22] , figure (2). Rubber ring 30 mm in diameter and 15 mm high was placed on the test block so that the intersection of a cross line and a groove 0.050 mm depth is in the center of the ring , the stone powder was weighed on an electronic balance (±0.2%) and mixed with distilled water that measured by using a graduated cylinder according to the ratios recommended by the manufacturer. After mixing the stone mix was poured inside rubber ring under vibration then the ring and the gypsum material was separated from the test block at 45 minutes according to manufacturer's instructions, AB distance (which represent the distance between groove 0.050 mm and groove 0.150 mm) was measured by using computerized soft ware program (Corel Draw x4), figure (3).

Fig. 2: Metal block for linear expansion test

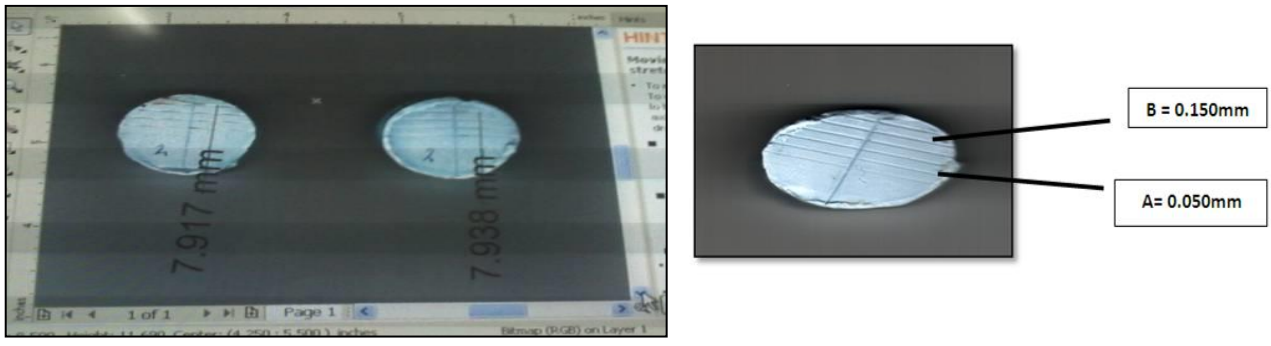

Fig. 3: Gypsum sample prepared for linear expansion test
(AB: represent the distance between four lines carved on the metal block)

3. **Surface detail reproduction**

To evaluate and compare Surface detail reproduction of conventional type IV dental stone (control group) with the disinfected gypsum specimens (experimental groups), 10 specimens for each gypsum group were prepared on the test block previously used for linear setting expansion test. Rubber ring (15 mm high and 30 mm in diameter) was used and the stone specimens were separated from the test block at 45 minutes according to manufacturer's instructions , the stone specimens were tested under X5 magnification microscope (Olympus BX51M with digital camera mounted on the microscope and connected to the computer) with low angle lighting, figure (4) .The surface detail reproduction will be satisfactory if the 0.050 mm depth groove is continuous for the length inside diameter of the plastic ring, figure (5).

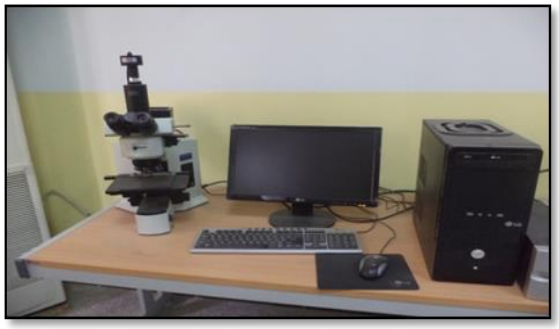

Fig.4: Low lighting microscope used for surface roughness evaluation

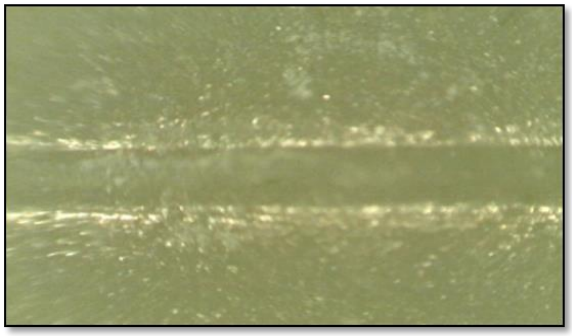

Fig.5: Optical microscope illustrates the continuity of 0.050 mm line regarding surface detail reproduction test

The following scoring system with rating values from one to four was used as follows [(2)]:

Rating 1: well defined, sharp detail and continuous line.

Rating 2: continuous line but with some loss of sharpness.

Rating 3: poor detail or loss of continuity of line.

Rating 4: marginally or completely discernible line.

4. **Compatibility with addition silicone impression material**

Compatibility of type IV dental stone with the elastomeric impression material was conducted according to ADA specification No.19, 10 stone samples were prepared for the same metallic block that used for the linear setting expansion test, a plastic ring (30 mm diameter and 15 mm high) was placed on the test block so that the groove 0.025 mm wide was reproduced on the gypsum surface, 10 vinyl polysiloxane (syringe type) elastic impressions were taken for the test block, figure (6) .Boxing was done for these impressions and the stone was poured inside the waxed impressions then after 45 minutes (according to manufacturer's instructions) stone samples were removed from the waxed impressions and the surface area was examined by using optical microscope with X5 magnification power. The gypsum compatibility is considered satisfactory if the 0.025 mm width groove is continuous for the length inside diameter of the plastic ring.

Fig. 6: Auto mix elastic impression material

5. **Compressive strength**

For Compressive strength test 10 stone samples were prepared using split mold 20 mm in diameter and 40 mm high according to ADA specification No.25, the split mold was placed on a glass plate so that the ends of the samples remained flattened and vibrated gently while the stone mix was poured inside the mold then the overfilled mold was covered with a second glass plate and pressed firmly. The specimens were removed from the split mold at 45 minutes (according to manufacturer's instructions) from the start of the mix, stored for 24 hours, then the stone samples figure (7) were crushed at a loading of 7.5 KN. the test was performed with hydraulic press testing machine, figure (8), the compressive strength was calculated according to the following formula: compressive strength = load (N) / surface area (mm^2). The average value of the 10 readings was dependent for the compressive strength test.

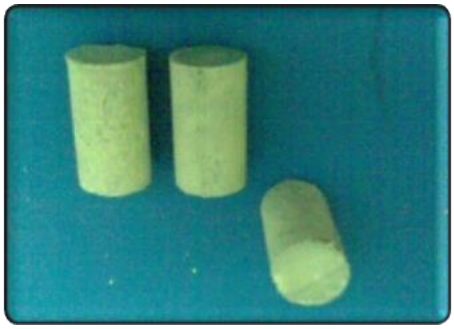

Fig. 7: Gypsum samples for compressive strength test

Fig 8: Hydraulic press machine

RESULTS

The addition of $AgNO_3$ and $CuSO_4$ disinfectant powders to the type IV dental stone showed a clear reduction in the initial setting time in comparison to the control group.

Table 1: Setting time for the control and experimental groups

Groups	Setting time	
	Minutes	Seconds
Control	11	00
Ag No$_3$0.5 %	10	10
$AgNO_3$ 1 %	8	30
$CuSO_4$ 0.5 %	4	33
$CuSO_4$ 1 %	6	50

The results of this study showed that the disinfectant agents produced a significant reduction in the mean value of the linear setting expansion in comparison to the control group, this result was found by ANOVA test but LSD test revealed a non significant difference between G1& G2, G1&G4 also between G1&G7 regarding the linear expansion mean values as shown in table (2)& table (3).

Table 2: Descriptive statistical analysis and ANOVA test of setting expansion for the control and experimental groups

Groups	Setting expansion (mm)			Groups' comparison			
	N	Mean	SD	df	F-test	P value	Sig.
(G1) control	10	7.9285	0.0111	29	6.591	0.005	**HS
(G2) $AgNO_3$ 0.5 %	10	7.8776	0.0067				
(G3) $AgNO_3$ 1 %	10	7.7619	0.1808				
(G1) control	10	7.9285	0.0111	29	31.749	0.000	**HS
(G4) $CuSO_4$ 0.5 %	10	7.8700	0.0718				
(G5) $CuSO_4$ 1 %	10	7.7760	0.0158				
(G1) control	10	7.9285	0.0111	29	7.312	0.003	**HS
(G6) Ethanol 70 %	10	7.8520	0.0759				
(G7) Propanol 70 %	10	7.9250	0.0406				

Table 3: LSD analysis test of setting expansion for the control and experimental groups

Studied groups	P- value	Sig.
G1 & G2	0.171	**NS**
G1 & G3	0.000	HS
G2 & G3	0.002	HS
G1 & G4	0.115	**NS**
G1 & G5	0.000	HS
G4 & G5	0.010	HS
G1 & G6	0.040	S
G1 & G7	0.971	**NS**
G6 & G7	0.043	S

****P<0.01 Highly significant.**

The addition of $AgNO_3$ and $CuSO_4$ to the type IV dental stone resulted in a statistically significant reduction in the mean values of compressive strength in comparison to the control group while a statistically in significant difference in the mean values of compressive strength was observed for the stone specimens after immersion in alcohols for 15 minutes (ethanol or propanol) in comparison to the control group, table (4).

Table 4: Descriptive statistical analysis and ANOVA test of compressive strength (MPa) for the control and experimental groups

Groups	Compressive strength N/m2 (MPa)			Groups' comparison			
	N	Mean	SD	df	F value	P value	Sig.
(G1) control	10	19.8465	0.8877	29	334.740	0.000	**HS
(G2) $AgNO_3$ 0.5 %	10	19.6485	0.4263				
(G3) $AgNO_3$ 1 %	10	13.4964	0.4454				
(G1) control	10	19.8465	0.8877	29	24.430	0.000	**HS
(G4) $CuSO_4$ 0.5 %	10	17.0330	1.0860				
(G5) $CuSO_4$ 1 %	10	16.9170	1.1882				
(G1) control	10	19.8465	0.8877	29	1.112	0.344	NS
(G6) Ethanol 70 %	10	18.6670	2.4183				
(G7) Propanol 70 %	10	17.5655	4.9473				

**** P<0.01 Highly significant.**

Further analysis using LSD test revealed that no significant differences were found between the control group and the experimental groups (G2, G6, G7), also a non significant difference was observed between G4 and G5 groups regarding the compressive strength of dental stone used in this study, table (5).

Table 5: LSD analysis test of compressive strength (MPa) for the control and experimental groups

Studied groups	P- value	Sig.
G1 & G2	0.484	NS
G1 & G3	0.000	HS
G2 & G3	0.000	HS
G1 & G4	0.000	HS
G1 & G5	0.000	HS
G4 & G5	0.809	NS

Table (6) showed that mixing high concentrations of $AgNO_3$ and $CuSO_4$ adversely affected the surface detail reproduction of type IV dental stone. None of the examined casts showed grade 4 surface quality.

Table 6: Presents the results of chi-square analysis (the percentage values) of the surface detail reproduction of the control and the experimental groups.

Groups	Rankings			
	I	II	III	Total
Control	8 (80%)	2 (20%)	0 (0%)	10 (100%)
$AgNO_3$ 0.5%	8 (80%)	2 (20%)	0 (0%)	10 (100%)
$AgNO_3$ 1%	0 (0%)	6 (60%)	4 (40%)	10 (100%)
$CuSO_4$ 0.5%	2 (20%)	6 (60%)	2 (20%)	10 (100%)
$CuSO_4$ 1%	1 (10%)	7 (70%)	2 (20%)	10 (100%)
Ethanol 70%	8 (80%)	2 (20%)	0 (0%)	10 (100%)
Propanol 70%	8 (80%)	2 (20%)	0 (0%)	10 (100%)
Total	35(50%)	27(38.6%)	8(%11.4)	(100%)70

X^2= 38.719, df =12, p-value = 0.000(HS), Likelihood ratio=46.135, df = 12, p-value=0.000(HS)

Table 7 showed that mixing high concentrations of disinfectant agents ($AgNO_3$, $CuSO_4$) with gypsum powder adversely affected the compatibility of type IV dental stone. None of the examined casts showed grade 4 surface quality.

Table 7: Presents the results of chi-square analysis (the percentage values) of the surface detail reproduction of the control and the experimental groups.

Groups	Rankings			
	I	II	III	Total
Control	8 (80%)	2 (20%)	0 (0%)	10(100%)
$AgNO_3$ 0.5%	7 (70%)	3 (30%)	0 (0%)	10(100%)
$AgNO_3$ 1%	0 (0%)	4 (40%)	6 (60%)	10(100%)
$CuSO_4$ 0.5%	3 (30%)	6 (60%)	1 (10%)	10(100%)
$CuSO_4$ 1%	0 (0%)	6 (60%)	4 (40%)	10(100%)
Ethanol 70%	8 (80%)	2 (20%)	0 (0%)	10(100%)
Propanol 70%	8 (80%)	2 (20%)	0 (0%)	10(100%)
Total	34(48.6%)	25(35.7%)	11(15.7%)	70(100%)

X^2= 45.718, df=12, p-value = 0.000(HS), Likelihood ratio= 54.179, df= 12, p-value= 0.000(HS)

DISCUSSION

In Prosthodontics, objects potentially contaminated with pathogenic microorganisms are transported between dental laboratory and dental clinic. It has been claimed that to avoid cross contamination, specific disinfection measures should be followed. In the literature, the usual solution to this problem has been to chemically disinfect either the impressions or gypsum casts [(1)].

In this study, gypsum specimens disinfected with either incorporation or immersion in disinfectant agents revealed the following results regarding the evaluated properties:

Setting time

The time elapsing from the beginning of mixing until the material hardens is called the setting time; certain penetrometers are dependant for measuring setting time of gypsum products like Gilmore needle and Vicat needle [(11)]. Following ADA specification No.25, the setting time was obtained using standardized Vicat apparatus. Regarding the result of this study it could be found that the disinfectant powders in the evaluated concentrations promoted a clear reduction in the Vicat setting time in comparison to the control group, this can be explained that $AgNO_3$ in high concentration increased the rate of dissolution of hemihydrates and subsequently made the hemihydrates more soluble. The setting reaction of gypsum products is affected by the type and the concentration of the chemical modifiers which are added within the gypsum materials, this finding is in agreement with Hatim *et al.* [(12)] While the addition of $CuSO_4$ in low concentration (0.5%) has shown a greater reduction the setting time of dental stone in comparison to 1%, this could be explained that some modifiers in high concentrations may precipitate and poison the nuclei of crystallization either by reducing the rate of solubility of hemihydrates or by inhibiting the growth of dihydrate crystals [(11).]

Linear setting expansion

The setting expansion of the dental stones is an important factor for many dental applications. The casts must have slightly larger dimensions to offset the impression material shrinkage and then ensure that the dental pieces are adequately manufactured, under ordinary conditions high strength dental stone has 0.08% to 0.10 % linear setting expansion [(6,17)]. Many factors may affect the setting expansion of gypsum products among them the technique of spatulation, condition of water (deionozed or not), the composition of the gypsum product [(6)]. In this study, the addition of disinfectant powders in low concentrations to the dental stone or immersion of stone specimens in 70% propanol did not adversely affect the dimensional stability of dental stone, Regarding the addition of disinfectant powders in high concentrations to the dental stone, the reduction in the linear setting expansion could be due to the changes in the morphology of the resulted gypsum crystals as a result to the disinfectant treatment and subsequently produce changes in the crystals thrust and tendency for expansion, this finding is in agreement with the finding of Hatim *et al.* [(12)].While for stone specimens immersed in 70% ethanol for 15 minutes, the change in the linear setting expansion could be due to interaction between the solution and dental stone [(22)] also this finding is in agreement with Sarma *et al.* [(24)] who found that immersion of

stone specimens 2% gluteraldehyde for 10-30 minutes showed negative shrinkage and relate the change to the erosion of the reproduced lines, surface erosion is perhaps the best measure of the reaction of the stone. Immersion of stone specimens in 70% propanol for 15 minutes showed no statistical significant difference in comparison to the control group, this is similar to the study of Abdelaziz *et al.* [15].

Compressive strength

The strength of gypsum – based products is usually expressed in terms of compressive strength, which is directly related to the material's ability to fracture resistance when subjected to compressive tensions. Thus the dental stone compressive strength is an important factor in the rehabilitation work in dentistry [13]. In the set gypsum material, the number of crystals formed during setting and their inter-meshing and enlargement determines the strength. Of the set material [14], the prepared dental stone specimens with the additives have shown a reduction in compressive strength in comparison to the control specimens, this could be either related to the presence of additional excess water in the mixture or to the decrease interaction (inter crystallization cohesion) between the gypsum crystals related to decreased amount of gypsum crystals as a result of Increased concentration of additives in a given volume of gypsum material. 1% $AgNO_3$ and 1% $CusO_4$ produce great reduction in compressive strength than the control group and other experimental groups, this may be related to the increase in the rate of reaction so that some of the hemihydrates crystals does not get hydrated to form dihydrate crystals, this increase the un reacted hemihydrates contents in the materials and thereby produces a weaker product [13].

Detail reproduction

The incorporation of disinfectant powders ($AgNO_3$, $CuSO_4$) in high concentrations adversely affected the detail reproduction of stone cast, this could be due to several alteration in the crystals formed during the stone setting reaction or could be attributed to the change in the water requirement of dental stone as a result of incorporation of the disinfectant powders leading to change in the recommended consistency for satisfactory detail reproduction [13,16]. The immersion of stone samples in 70% ethanol or 70% propanol for 15 minutes did not affect their surface detail reproduction; this finding is in contrast with Sarma *et al.* [24] who found that immersion of stone specimens in 2% gluteraldehyde for 10-30 minutes showed alteration.

Gypsum compatibility with silicone impression materials

Mixing the dental stone with high concentrations of disinfectant powders did harm the compatibility of dental stone while 15 minute immersion of stone specimens in either 70% ethanol or 70% propanol did not affect the compatibility of dental stone ,this finding is in agreement with Abbas and Ibrahim [16] and Marcos *et al.* [17] , it could be due to some kind of interaction of disinfectant powders with that of impression material leading to reduction in the sharpness of the line reproduced also could be due to low wetting behaviors of the disinfected dental stone against the surface of silicone impression material.

As conclusion; within the limitations of this study, the newly introduced mixing method revealed that 0.5% silver nitrate powder as well as 15 minutes immersion of the set stone specimens in 70% ethanol or 70% propanol did not appear to have an adverse effect on the tested physical and mechanical properties

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