Effectiveness of Some Disinfectant Solutions on the Compressive Strength and Hardness Properties of Two Types of Dental Stone

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Abstract
Background The transferring of infectious agent by blood and saliva through dental casts increase the risk of cross infection, so disinfection is mandatory. The goal of this research was conducted to assess the influence of chemical disinfection solutions on (hardness, compressive strength) properties of two dental stone gypsum materials. **Materials and methods** A sample of 224 specimens of dental stones [type IV (diestone), and III (stone)] were prepared (n=7). The specimens prepared for each tested groups of compressive strength and hardness test using split mold technique (20 mm in diameter and 40mm height). Three types of experimental disinfectant solutions were used (sodium hypochlorite, chlorhexidine, and glutaraldehyde), in addition to distill water as a control group. For each disinfectant group, stone specimens were disinfected by two methods, the immersion and mixing with solution completely. After disinfection was completed, compressive strength was measured using automatic double chamber machine at loading rate of 2900 (±490 N/min) and 300 (±50 Kg/ min), while hardness measurement was done by using Rockwell hardness test (R scale) with minor loud of (10 Kg) and major load of (60 Kg). Five measurements for each sample were tested and the average was taken. **Results** statistical analysis (t-test) showed non-significant changes between the two techniques of immersion and mixing disinfections for both stone materials in chlorhexidine only, while it was significant on the other tested groups. In addition, ANOVA test showed significant changes between disinfectant groups regarding of compressive strength property. On the other hand, hardness measurement test observed that sodium hypochlorite had no reading on the device after using mixing technique. A T-test revealed insignificancy between two techniques of disinfection except in distilled water control group of stone material. While ANOVA test revealed a significant change between disinfectant solutions except in stone gypsum material. **Conclusions** the results showed that glutaraldehyde and chlorhexidine solutions had a better effect than sodium hypochlorite in regard to the tested properties.

Keywords: Dental stone, disinfection, compressive strength, hardness.

Introduction

The most widely used model and die materials from the past till nowadays is gypsum products (Choudhary et al. 2016; Niekawa et al. 2017). The gypsum-based product that is used in dental stones and plasters is calcium sulfate hemihydrate, $CaSO_4 \cdot ½ H_2O$ (Singh and Middendorf, 2007, Craig, 1997). Type IV and V dental stones are produced by taking the α-calcium sulfate hemihydrate one step further by steaming it in a mixture of 30% calcium chloride. This results in crystals being formed in more symmetrical shapes, thus leading to improved stones that possess the highest densities of the five types of stones (Won and John, 2012; Sharma et al.2013, Donovan T and Chee, 1989). The oral cavity is considers a resource of infection as it enclose numerous microorganisms, (Laheij et al. 2012), so any dental instruments or impressions infected with microorganisms that inadequately washed or sterilized may result in cross-contamination (Elnaz et al. 2015), which is the transmission of pathogenic microorganisms, resulting in cross-infection (Pereira et al. 2012). In prosthodontics, infection control and disinfection procedures have been developed with specific importance on the disinfection of impressions and casts used for the construction of prostheses (Anaraki et al. 2013). Deep penetration of microorganisms through dental casts due to its porous structure and highly hydrophilic nature, making the surface disinfection techniques ineffective (Breault et al.1998; McDonnell and Denver., 1999). Transmission of infective agents to the casts from blood and saliva through impressions, occlusion rims, record bases, and trial dentures will lead to cross-contamination (Abdullhh 2006; Rathika et al. 2017). A cast from an accurately sterilized impression may become contaminated by a technician or clinician Even with effective disinfection of impressions, (Berg 2005; Al Mortadi et al. 2019). Disinfection means a clinical stage aimed to wipe out most microorganisms (bacteria, viruses and spores) from the surface of an impression (Carvalhal 2011; Rutala and Weber, 1999). Disinfectants must do efficiently as antimicrobial agents but not negatively influencing the dimensional accuracy (Moser et al. 1975) or hardness property (Khalid and Edward, 2002). Surface hardness is a very important property for gypsum cast that corresponds to the reproduction of intimate surface details of recorded or facial structures in the working cast which can be transferred to the finished prosthesis or effect compressive strength which important to resist fracture during flasking of the denture, and other feature fidelity of gypsum cast (Tuncer et al. 1993; Casemiro, 2007; Koosha et al. 2017, Davila et al. 2018). This study aims to evaluate compressive strength and hardness of two types of dental gypsum materials under the effect of chemicals disinfection.

Materials and Methods

A. Preparation of gypsum specimens

Dental stones samples were prepared from two types of dental gypsum (n=7), these are type III (Zhermach, Italy) and type IV (Italy, Zhermach); the powder/water ratio was used according to the manufacturer instructions. For type III dental stone was used powder/water ratio (100g/25ml). Distilled water was used for the preparation of tested sample. The mixing water temperature was maintained at 23(± 2 °C). The powder was added to the accurate amount of water and allowed to infuse for 30 seconds. Then it was mechanically mixed by using mechanical vacuum mixer (Moslehifard et al, 2013) for 30 seconds as shown in figure 1. After that, dental stone of type III was directly poured in the mold using mechanical vibrator, while dental stone of type IV, the powder/water ratio was 100g/20ml according to manufacturer instructions. After complete setting (nearly 45 minutes), both type III and IV stone specimens were separated from the molds and left 24 hours for drying at 23 (±2) ºC before testing.

Figure (1): Vacuum mixer.

B. Disinfectant solutions

Three types of experimental disinfectant solutions have been used: a 5.25% of sodium hypochlorite (ABC Deterjan san/Osmaniye/Turkey) 0.12% of Chlorhexidine Digluconate. (Khalaf and Mahmood, 2013) (Ciutat de Granada, Barcelona, Spain), 2% glutaraldehyde (Ivanovski et al. 1995; Mohammad et al. 2014) and distilled water as a control group. Each solution was used in two approach; immersion method when the sample was immersed in the solution for 30 minutes (Kumar R et al. 2012), and the mixing method when the disinfectant solution was mixed with powder instead of water.

C. Properties measurement

1. Compressive strength measurement

112 dental gypsum type (IV) and (III) specimens were prepared for compressive strength test by using split mold (40 mm height and 20 mm in width), corresponding to "ADA specification No.25", to maintain the ends of the samples flattened a glass plate was used under the mold and vibrated gently whereas the stone mixture was poured in the mold then the top of the mold was covered with a another glass plate and pressed tightly. According to manufacturer›s instructions, the specimens were separated from the mold after 45 minutes from starting of the mixing. For immersion method, the samples were immersed for 30 minutes in disinfectant solution then tested after 24 hours. For mixing method the specimens tested also after 24 hours, automatic double chamber compressive machine was used at a loading rate of 2900 (± 490 N/min) and (300± 50 Kg/ min) for dental stone according to ADA specification No.25 as shown in figure 2, figure 3 and figure 4.

Figure (2): Mold of compressive speic **Figure (3): Samples preperation.**

Figure (4): Compressive test machine.

2. Measuring of the Surface Hardness

112 dental gypsum type (IV) and (III) specimens were prepared for surface hardness test by using split mold (20 mm in width and 40 mm height) corresponding to "ADA specification No.25". To ensure that the specimen with flattened end a glass plate was used to place under the mold and stone mixture was vibrated gently when poured in the mold then another glass plate was covered the top of the mold and pressed firmly. After 45 minutes from the start of the mixing the specimens isolated from the split mold (following to manufacturer›s instructions). An incubator was used to store all the samples at a temperature 23 (±2ºC) and relative humidity of 50(±10%). Hardness means value depend on the depth of penetration of indenter into the subjected material. The smooth flat surface which was poured against flat glass plate was tested. Rockwell hardness test (R scale) was used with minor load of (10) kg and major load of (60) kg (Kumar et al. 2012). A steel ball (½inch) in diameter was used. Five readings for each specimen were tested; the point selected in the same line and then the average of the reading was taken (figure 5 and figure 6).

Figure (5): Rockwell hardness tester.

Figure (6): Gypsum sample tested by hardness.

D. Statistical Analysis

The difference between two techniques of disinfection was determined by using T-test, in addition to analysis of variance and Duncan's multiple range tests to observe the significance among disinfectant groups in which ($p \leq 0.05$).

Results

Statistical analysis for compressive strength of distone material table (1) revealed a non-significance change in chlorhexidine group and significances in the other three groups. Analysis of variance in table (2), showed a significant difference between disinfectant groups concerning control group (distill water). For stone material, compressive strength measurement in table (3) observed also a non-significant difference in chlorhexidine group and significant difference in the other group while table (4) revealed a significant difference in both immersion and mixing procedures, in which sodium hypochlorite showed the least compressive strength compared with other disinfectants procedures. For hardness measurement of both stone and distone gypsum materials there were no readings on hardness device for sodium hypochlorite group after mixing with disinfectant solution that's why, this group was excluded statistically in (t-test) analysis. Table (5) showed no significant difference between the two procedure of disinfection (immersion and mixing).Table (6) observed a significant difference between disinfectants in which the glutaraldehyde observed the highest hardness measurement, table (6)

showed a significant difference between disinfectant groups in which chlorhexidine showed the least hardness value. In stone material hardness measurement, table (7) showed a significant difference between the two procedures of the preparation in the control group of distill water. Table (8) observed a significant difference in hardness reading of stone material after immersion between disinfectant groups. Also it indicated a non-significant difference between the groups of disinfections in hardness reading of stone material as significant value of $p \geq 0.05$.

Table (1): T-test shows the influence of disinfectant solutions on compressive strength of distone gypsum material.

Groups	N	mean	SD	T-value	Sig
Sodium immersion hypochlorite mixing	7 7	35.4629 5.5386	5.0092 1.93828	14.74	.000
Chlorhexidine immersion mixing	7 7	26.6171 28.4471	4.1358 5.0924	-0.738	0.475
Glutaraldehyde immersion mixing	7 7	27.0357 35.4043	5.10576 5.2941	-3.010	0.011
Distilled water immersion mixing	7 7	24.9057 40.0829	1.9474 3.3756	-10.304	0.000

Table (2): One-way ANOVA-test shows the influence of disinfectant solutions on compressive strength of distone gypsum product.

Groups	Summation of Squares	df	Means of Squares	F	Significance
Immersion between group Inside group total	469.626 432.358 901.984	3 24 27	156.542 18.015	8.690	.000
mixing between the group inside group total	4927.566 414.678 5342.244	3 24 27	1642.522 17.268	95.063	.000

Table (3): T- test shows the effect of disinfectant solution on compressive strength of stone gypsum material.

Groups	N	Mean	SD	T-value	Sig
Sodium immersion Hypochlorite mixing	7 7	23.9129 7.8414	3.51 1.48	11.141	0.000
Chlorhexidine immersion mixing	7 7	24.24 24.085	3.624 3.553	.080	0.937
Glutaraldehyde immersion mixing	7 7	25.46 20.762	3.855 2.732	2.634	0.022
Distilled water immersion mixing	7 7	29.02 19.25	2.452 1.542	8.923	0.000

Table (4): One -way ANOVA-test shows the influence of disinfectant solutions on the compressive strength of stone gypsum material.

Groups		Summation of squares	df	Means of square	F	Significance
Immersion	between the group	115.173	3	38.391	3.313	.037
	Inside group	278.146	24	11.589		
	total	393.319	27			
mixing	between the group	1046.144	3	348.715	56.499	.000
	inside group	148.130	24	6.172		
	total	1192.274	27			

Table (5): T- test shows the effect of disinfectant solutions on the hardness of distone gypsum material.

Groups		N	Mean	SD	T-value	Sig
Chlorhexidine	immerse	7	65.5029	7.74984	1.385	0.191
	mixing	7	61.2943	2.13856		
glutaraldehyde	immerse	7	74.1843	6.11531	o.729	0.480
	mixing	7	71.1771	9.03516		
Distilled water	immerse	7	66.6500	2.19761	-.126	0.902
	mixing	7	67.0343	7.75561		

Table (6): One- way ANOVA-test shows the outcome of the disinfectant solutions on the hardness of distone gypsum material.

Groups		Summation of squares	df	Means of square	F	Significance
Immersion	between the group	795.700	3	265.233	3.950	.020
	Inside group	1611.623	24	67.151		
	Total	2407.324	27			
mixing	between the group	344.824	2	172.412	3.534	.051
	inside group	878.142	18	48.786		
	Total	1222.966	20			

Table (7): T- test shows the influence of disinfectant solutions on the hardness of stone gypsum material.

Groups		N	Mean	SD	T-value	Sig
Chlorhexidine	immerse	7	59.53	11.62506	-1.803	0.097
	mixing	7	68.1286	4.90625		
Glutaraldehyde	immerse	7	73.8371	13.28213	-.120	0.907
	mixing	7	74.5957	10.18974		
Distilled water	immerse	7	82.6271	4.41557	2.543	0.026
	mixing	7	66.2457	16.45850		

Table (8): One- way ANOVA-test shows the influence of disinfectant solutions on hardness of stone gypsum material.

Groups		Summation of squares	df	Means of square	F	Significance
Immersion	between the group	2895.607	3	965.203	10.710	.000
	Inside group	2162.868	24	90.120		
	Total	5058.475	27			
mixing	between the group	268.547	2	134.274	1.010	.384
	inside group	2392.707	18	132.928		
	Total	2661.254	20			

Discussion

Gypsum products are extensively used in dentistry for a variety of purposes ranging from construction of study models and casts duplication of soft and hard tissues of oral cavity required for crown and bridge work, fabrication of complete dentures or maxillofacial rehabilitation. Besides having extensive use in Prosthetic Dentistry, it is used widely in other branches of dentistry as well (Choudhary et al. 2016). Gypsum materials to be clinically beneficial should have high compressive strength and fracture, abrasion, resistance (Tuncer et al. 1993). Mostly, the factors like powder/ water ratio, working time, the bulky of the mixture, chemical structure, free water content inset product, humidity, storing temperature and elapsed time after the cast is poured affecting the compressive strength of gypsum products (Craig, 1997). This study results showed the compressive strength with the lowest value for two types of stones when mixed with sodium hypochlorite disinfectant solution. A study by Mohammad et al. showed a significant reduction in compressive strength of dental stone type IV when mixing with a high concentration of sodium hypochlorite (Mohammad et al. 2014). The considerable alteration elicited by the integration of sodium hypochlorite is owing to the creation of a low-solubility salt which, when exist in great concentrations, alters the crystallization nucleus and consequently affects properties of gypsum products. However, in 1989 obtained opposite results via a greatly watery concentration of sodium hypochlorite (Donovan T and Chee, 1989). Which may be described the point of some retardants act as accelerators when in low concentrations. A study by Davila showed the brittle samples of compressive strength of type IV dental stone are those with the addition of 100% sodium hypochlorite 1%. Results of this study could in agreement with some prior studies that when used of a high concentration of sodium hypochlorite was significantly reduced compressive strength (Davila et al. 2018). Chlorhexidine disinfectant solution result showed a non-significant change in compressive strength of type III and IV dental stone in both (immersion and mixing) procedure. Therefore, it can be used for disinfection of gypsum cast. Khalaf H and Mahmood in 2013 showed in their study that gypsum specimens integrated with chlorhexidine digluconate mouth wash revealed considerable antimicrobial activity (growth inhibition zone) against Staphylococcus aureus and Streptococcus mutans associated with a heightened concentration of CHX disinfectant. For hardness measurement, the study observed that there is a significant reduction in this physical property when sodium hypochlorite solution mixed with dental stone, as there is no reading result on the hardness measuring device. For this reason this group in this study was excluded. In present study and for both types of dental stones that immersed in sodium hypochlorite, a decrease in surface hardness was reported. Another study showed a decrease in surface hardness of dental stones after spraying them with the sodium hypochlorite and virkone disinfectants (Moslehifard et al. 2013(. Glutaraldehyde disinfectant solution observed the highest hardness measurement for distone gypsum type with immersed procedure. In 1995 a research by Ivanovski observed that glutaraldehyde was the best efficient disinfectant with the minimum adverse effects on the physical properties of the set cast (Ivanovski et al. 1995). In which it goes online with the result of this study.

Conclusions

Sodium hypochlorite cleanser decreased the compressive strength when mixed with both type III and IV gypsum materials and there was no hardness measurement for both materials during mixing technique. Glutaraldehyde cleanser was better than other groups in regard to the compressive strength and hardness tested properties in both stone and distone gypsum materials.

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