Compressive strength and surface roughness of die stone cast after repeated disinfection with sodium hypochlorite solution

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ABSTRACT

Background: The transmission of oral pathogen to impression and subsequently on to gypsum cast has been demonstrated, and dental stone cast have to be disinfected to prevent the transmission of infectous disease, this infection process may affect some physical or mechanical properties of the cast. The aim of the study was to evaluate the compressive strength and surface roughness of type IV dental stone cast after repeated immertion in and sprying using (0.5%) sodium hypochlorite disinfectant solution.

Materials and methods: A total of (42test blocks) were prepared and divided to (3) three groups (14each) (control spray and immersion) for the surface roughness test. These were subdivided into (2) groups (7) each to be tested after (24 and 48 hours) the same distribution of the test block were followed for the compressive strength test. For each test 1/3 of the test black immersed in the disinfectant solution for 30 minutes then allowed 24 hours for be each drying this was repeated 5times before being tested, 1/3 of the specimens were sprayed with the disinfectant 5 times in an interval of 24 hours for bench drying the last 1/3 blokes were the control.

Results: Immersing or spraying with hypochlorite solution significantly decreased the compressive strength after 24 hours and increased after 48 hours. As for the surface roughness the results showed that both spraying and immersion significantly increased the value of the roughness, with immersion as a higher value. Spraying with (0.5%) sodium hypochlorite solution provide smoother dental stone casts surfaces and adequate compressive strength when allowed for (48hours) compared to immersion group bench drying.

Conclusion: Dental stone casts disinfected by immersion method showed a higher surface roughness than those disinfected by spraying.

Keywords: Die stone, roughness, strength disinfection, immersion, sprying. (J Bagh Coll Dentistry 2010;22(3):27-33).

INTRODUCTION

The oral environment harbors a large number of microorganisms blood and saliva may carry high concentration of potentially infective viruses or bacteria that may produce the common cold, Herpes, Hepatitis B, Pneumonia, Tuberculosis and suspected mode of transmission of AIDS[1].

Effective infection control procedures should be exercised by all dentists in office, dental auxiliaries and dental technicians to prevent the transmission of diseases. The dental office has primary responsibility for infection control and if disinfection procedures are not practiced, a cycle of cross contamination may occur, thereby exposing personnel and patient to infection [2].

Disinfection of dental impression is a weak point in the dental hygiene chain, because not all impression materials could be disinfected without adversely affecting the properties of the impression [3].

Because the heat sterilization process would be damaging to a dental cast, 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[4,5,6]

This study was conducted to investigate the change in the compressive strength and surface roughness of type IV dental stone casts after several times of immersion or spraying with (0.5%) sodium hypochlorite disinfectant solution.

Disinfection by Spraying

ADA Council on scientific affairs and ADA Council on dental practice[6] stated that stone casts can be properly disinfected by spraying with or immersing in hypochlorite or iodophor solutions. Casts should be sprayed rather than immersed in disinfecting solutions, because some studies have shown damage to the surface in only a few minutes in water-based solutions. 1:10 sodium hypochlorite solution has been shown to have minimal effect on cast surfaces[7,8].

The American Council on Dental Therapeutics Council on Services and Dental Laboratory Relations (1985)[2] stated that models can be disinfected with a spray of Iodophor used according to the manufacturer's instructions. A test of three disinfectant sprays (phenol, lodophor, and glutaraldehyde) found that each

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could be used safely and effectively on gypsum products with out weakening the compressive strength. The problem with spray disinfectants is the inability of the solution to completely cover and maintain contact with all surface of the cast for the required amount of time. Depending on the angle of the spray dispenser, undercut areas and inter-proximal surfaces may be missed in the application of the solution. Also, the porosity of stone casts requires that the surface be completely saturated for the disinfectant to be effective, which is difficult to achieve and maintain with a topical spray [9] Berko (2001)[10] stated that the spraying method of disinfection by Madacide disinfectant solution had no effect on both the detail reproduction and the compressive strength. It produced a significant decrease in both dimensional stability and surface hardness properties.

Disinfection by Immersion

Disinfectants used for immersion of dental casts are diluted in water, thus creating a potential problem. [11] Rudd et al 1970 showed that immersing a stone cast in tap water alone for (15) minutes altered surface properties. Since it is recommended that a cast remains submerged in the disinfectant solution for up to (30) minutes to achieve a disinfected surface (ADA)[6]. the effect of immersion of set die stone in several disinfectants commonly used in dentistry has been evaluated. The effects of immersion disinfection of a completely set stone cast with gluteraldehyde, phenol, iodophor, and chlorine disinfectants were investigated by Sarma and Neiman [12]. The authors reported that (0.525%) solution (1:10 solution) of sodium hypochlorite produced the least undesirable effects with regard to surface erosion, surface hardness, compressive strength, and chemical reactivity when compared with other disinfectants.

A study aimed to comparing dimensional alteration, superficial texture and compressive resistance of stone dies submitted to different disinfection methods: (30) minutes immersion in (1%) sodium hypochlorite or in (2.2%) alkaline glutaraldehyde and addition of (2.2%) alkaline glutaraldehyde or (5%) sodium hypochlorite to the gypsum. It was found that chemical disinfection did not cause significant dimensional alteration in stone dies; superficial texture was altered; immersion in disinfectant solution during (30) minutes, as well as the addition of the disinfectant to the gypsum, reduce the compressive resistance of dies[13].

MATERIAL AND METHODS

The preparation of the test specimens and test procedures were conducted at (23±2)°C temperature and (50±10)% relative humidity, all the equipments and materials used in this study were maintained at this conditions for at least ten hours prior to experimentation. The tested solutions (distilled water and disinfectant solution) were also stored under the same conditions, the stone sample kept in a moisture resistant container under similar conditions for at least ten hours prior to experimentation.

Concentrated sodium hypochlorite solution "FAS bleach" was supplied as 6.2% by manufacture. A sample from the concentrated "FAS" solution was tested in Salahaddin University/College of Education-Chemistry department to certify the percentage of available sodium hypochlorite; it was proved that it contains 6.2% sodium hypochlorite as it was labeled on the product.

The dilution of this disinfectant was done with distilled water at room temperature according to the following equation (dilution law advocated by Summerlin, 1981) the law of dilution:

Volume (1) X Concentration (1) = Volume (2) X Concentration (2)

In order to obtain 800ml of 0.5% sodium hypochlorite solution the law of dilution was followed

Volume (1) X 6.2% = 800 X 0.5%

Volume (1) = 64.5ml

So 64.5ml of 6.2% concentrated bleach is added to 745.5ml of distilled water. However because of the poor stability of sodium hypochlorite solution over time, it was made fresh daily to ensure efficacy.

A special split mold was made of brass according to ADA specification number 25 in order to prepare the cylindrical stone specimens with dimensions of 20mm diameter and 40mm length for compressive strength testing (Figure 1).

The specimens were removed from the split mold after half an hour from the start of mixing, and stored in air at room temperature 23.0±2.0°C and 50±°10% relative humidity for 24 hours before testing of control group specimens and disinfection of spray and immersion group specimens.

A total of 84 dental stone specimens were divided into three main groups (Control group, Immersion group and Spray group) each group composed of 28 specimens. The control group was subdivided to compressive strength test 14 specimens; seven 7 specimens were tested after 24 hours from the start of mixing. Seven 7 specimens were tested after 48 hours from the

start of mixing. Surface roughness test (14 specimens). Seven 7 specimens were tested after 24 hours from the start of mixing. Seven 7 specimens were tested after 48 hours from the start of mixing.

Spray group specimens (28 specimens) were subjected to spray disinfection for five successive days in an interval of 24 hours for bench drying, after the last disinfection (5^{th} day) the specimens were subdivided and tested as in control group.

Immersion group specimens (28 specimens) subjected to immersion disinfection for five successive days in an interval of 24 hours for bench drying, after the last disinfection (5^{th} day) the specimens were subdivided and as previously mentioned.

Disinfection by immersion was done using a suitable sized container filled with 800ml of the prepared (0.5%) sodium hypochlorite disinfectant solution, where the cylindrical specimens of type IV dental stone were immersed in for 30 minutes at room temperature (Figure 2).

The specimens were then removed from the solution and allowed to air dry for (24) hours at room temperature of (23±2°C) and (50±10%) relative humidity. A pair of tweezers was used to pick up the stone specimens into and from the disinfectant solution the process of immersion disinfection was repeated five times in an interval of 24 hours. A five-cycle sequence of disinfection was chosen as an average for the number of applications necessary in construction of complete or removable partial dentures from the final impression appointments through delivery of the prostheses. After the last disinfection (5^{th} day) the specimens were bench dried at room temperature[14].

Disinfection by spraying was done by placing the stone model specimen in the center of a rounded deep container; the container was labeled from four areas a special stand designed and fabricated especially for the purpose of holding the spray container at fixed height, distance and angle from the stone specimen to be sprayed in order to standardize the spraying procedure (Figure 3).

Each aspect was sprayed until saturation of the surface of the stone specimen was apparent, that is the liquid spray no longer penetrated the stone whereby the liquid residue was evident on the stone surface. The stone specimens were then wrapped in a disinfectant-moistened paper towel to maintain the concentration of the surface disinfectant for the allowed time (30 minutes).

The test for compressive strength was conducted on a digital compressive strength testing machine which was so designed that prior to testing. Data regarding the shape and dimensions of the specimen are introduced through the digital screen of the machine, such as Shape: Cylindrical, Diameter: 20 mm, and Height: 40 mm. The specimen placed on the testing machine in a way that the top and the bottom of the specimen in contact with steel, flat, rigid platens (Figure 4). The specimens were loaded till crushed, according to the shape and dimensions of the specimen; the loading rate and the cross head speed were automatically set by the machine. The maximum load in Kilo Newton (KN) carried by the specimen and the compressive strength in N/mm2 were registered as shown on the digital screen of the machine.

Surface Profilometer was used to measure surface roughness, with a diamond stylus which travels on a straight line along the surface. The average surface roughness for the prepared stone specimens were expressed and calculated as Ra value in micrometer with the aid of the profilometer. (Figure 5) the Ra value was the arithmetic mean roughness value of the departure of the profile above and below a mean reference line[15]. Average surface roughness (Ra) was measured at three locations randomly on the surface of each specimen; each measurement was made over a tracing distance of 6mm at the accuracy of (0.01µm), and then the mean of the three readings was obtained and used in this study. All measurements were recorded by one operator.

RESULTS

The results of compressive strength test revealed that repeated disinfection of dental stone specimens with (0.5%) sodium hypochlorite solution both by spraying and immersion produced a highly significant effect on the compressive strength value. The dental stone specimens disinfected five times in an interval of 24 hours for bench drying. The results of the specimens that were tested 24 hours after the last disinfection (5^{th} day) are shown in table 1.

Immersion group showed the lowest mean value (225.729 kg/cm^2), spray group showed higher mean value than immersion group but less than control group (257.449 kg/cm^2). The control group specimens were tested after 24 hours from the start of mixing without subjecting them to disinfection; they showed the highest mean value (300.073 kg/cm^2).

One way analysis of variance (ANOVA) was performed to test the difference in the compressive strength means among the three groups table. Statistical analysis by (ANOVA)

test showed a highly significant (H.S.) difference between the test groups.

Statistical comparison between the mean of each testing group and that of the control group was done by using student T-test analysis table 2. From the results obtained it was found that both spray group and immersion group showed a decrease in the compressive strength value and this decrease was highly significant (P<0.01). Also using T-test analysis the mean value of immersion group showed a highly significant decrease comparing with that of spray group.

The results of the specimens that were tested 48 hours after the last disinfection (5^{th} day) are shown in table 3.

Immersion group showed the highest mean value (520.233kg/cm^2), spray group showed higher mean value than control group but less than immersion group (464.344kg/cm^2). The control group specimens were tested after 48 hours from the start of mixing without subjecting them to disinfection; they showed the lowest mean value (363.682 kg/cm^2).

One way analysis of variance (ANOVA) was performed to test the difference in the compressive strength means among the three groups. Statistical analysis by ANOVA test showed a highly significant (H.S.) difference between the test groups.

Statistical comparison between the mean of each testing group and that of the control group was done by using student T-test analysis table 4. From the results obtained it was found that both spray group and immersion group showed an increase in the compressive strength value and this increase was highly significant (P<0.01). Immersion group showed an increase in the mean value when compared with the mean value of spray group, but the T-test analysis revealed that this increase was not significant.

Using t-test analysis between the means of each group specimens tested after (24) hours and the same group specimens tested after (48) hours revealed that there was a highly significant difference between their mean values. The results are shown in table (5).

Immersion group showed the highest mean value (2.50 µm), spray group showed higher mean value than control group but less than immersion group (1.49 µm). The control group specimens were tested after (24) hours from the start of mixing, without subjecting them to disinfection; they showed the lowest mean value (0.45 µm) for the surface roughness as shown in table 6.

One way analysis of variance (ANOVA) was performed to test the difference in the surface roughness mean values among the three groups. Statistical analysis by ANOVA test showed a highly significant (H.S.) difference between the test groups.

Statistical comparison between the mean of each testing group and that of the control group was done by using student T-test analysis. From the results obtained it was found that both spray group and immersion group showed an increase in the surface roughness value and this increase was highly significant (P<0.01). Using T-test analysis the immersion group showed a highly significant increase in surface roughness mean value comparing with that of spray group (P<0.01) as shown in table 7.

Immersion group showed the highest mean value (3.35µm), spray group showed higher mean value than control group but less than immersion group (1.32µm). The control group specimens were tested after 48 hours from the start of mixing without subjecting them to disinfection; they showed the lowest mean value (0.56µm). as shown in table 8.

One way analysis of variance (ANOVA) was performed to test the difference in the surface roughness mean values among the three groups. Statistical analysis by ANOVA test showed a highly significant (H.S.) difference between the test groups.

Statistical comparison between the mean of each testing group and that of the control group was done by using student T-test analysis. From the results obtained it was found that both spray group and immersion group showed an increase in the surface roughness value and this increase was highly significant (P<0.01). Using T-test analysis the immersion group showed a highly significant increase in surface roughness mean value comparing with that of spray group (P<0.01) as shown in table 9.

Using t-test analysis between the means of each group specimens tested after 24 hours and the same group specimens tested after 48 hours revealed that there was no significant difference between them, except for the immersion group that showed a highly significant difference. The results are shown in table 10

DISCUSSION

After reviewing the literatures it has been found that previous studies regarding the effects of spray disinfection of dental stone casts with (0.5%) sodium hypochlorite solution on the compressive strength and surface roughness of the cast could not be traced, therefore agreement and disagreement with other studies will be very limited.

Sodium hypochlorite disinfectant solution was used in this study because one of the ADA-recommended disinfectants is chlorine compounds such as sodium hypochlorite solution (1:10 dilution)[16].

A five cycle sequence of disinfection was chosen as an average for the number of applications necessary in construction of complete or removable partial dentures from the final impression appointments through delivery of the prostheses.

On the basis of the results of this study, specimens tested after 24 hours from the last disinfection process showed that both spray disinfection and immersion disinfection processes caused a reduction in the compressive strength value when compared with the control group specimens, and this reduction was highly significant statistically.

The explanation for the decrease in compressive strength value after immersion in and spraying with 0.5% sodium hypochlorite solution could be that immersion of completely set gypsum cast in water reduces the compressive strength compared to the dry casts, even 24 hours bench drying could not be enough for the specimens to dry completely, so still there was excess water present. As the strength of the set gypsum is due to the cohesion of the crystals themselves in contradistinction to the interlocking of the crystals during growth, so any excess water present will reduce the cohesion of the crystals. Only when this excess water is eliminated the intercrystalline cohesion is entirely effective in its contribution to the strength[17].

Although there is reduction in compressive strength value both for the specimens of immersion group and spray group, but the specimens of spray group showed less reduction in compressive strength value compared with the specimens of immersion group. This may be attributed to the fact that when a specimen is sprayed with a specific solution it absorbs fewer amounts than if it immersed in the same solution. So the amount of free water left within the specimens of spray group will be less than that of immersion group specimens as a result their compressive strength will be higher.

Repeated spraying disinfection and immersion disinfection of (type IV) dental stone casts with 0.5% sodium hypochlorite disinfectant solution and subsequent drying will increase the compressive strength value when 48 hours left for bench drying after the last disinfection cycle (5^{th} day). This increase in compressive strength value was highly significant statistically. This result disagreed with a study conducted by Abdulla [14] since the specimens were tested after 24 hours from the last disinfection not after 48 hours as in this study.

A possible explanation of increased compressive strength may be that the sodium hypochlorite may assist or increase the adhesion between the dihydrate crystals.

The results in this study showed that the stone casts that were subjected to spray disinfection and those that were subjected to immersion disinfection using 0.5% sodium hypochlorite solution have a significant difference in surface roughness values.

Dental stone casts that were immersed in the disinfectant solution five times with subsequent bench drying showed higher surface roughness value than the specimens of the spray group and control group. Although the increase in the surface roughness value of spray group was highly significant when compared with the control group, but it was less than that of immersion group specimens. The increase in the surface roughness value of the spray and the immersion groups could be due to the etching effect of the disinfectant solution on the stone surface[18]. The immersion group showed higher surface roughness value than the spray group. This may be due to the fact that immersing a specimen in a specific solution absorbs the solution more than if it is sprayed with it.

Figure 1: Special split brass mold for preparation of compressive strength and surface roughness test specimens.

Figure 2: Immersion of seven specimens in the disinfectant solution

Figure 3: spraying procedure was performed at a fixed distance and fixed angle

Figure 4: stone specimen under compressive strength test

Figure 5: Surface roughness testing of a stone specimen

Table 1: Descriptive statistical analysis of compressive strength test after (24) hours

Compressive Strength value in kg/cm^2 tested after (24) hours				
Group	**Mean value**	**S.D.**	**Max. value**	**Min. value**
Control	300.073	24.767	321.735	254.388
Spray	257.449	15.85	281.122	237.245
Immersion	225.729	18.336	254.388	193.367

Table 2: Student t-test analysis of compressive strength tested after (24) hours

	P-value	**Significance**
Control-Spray	0.00329	H.S.
Control-Immersion	0.00005	H.S.
Spray-Immersion	0.00469	H.S.

Table 3: Descriptive statistical analysis of compressive strength tested after (48) hours

Compressive Strength value in kg/cm^2 tested after (48) hours				
Group	**Mean value**	**S.D.**	**Max. value**	**Min. value**
Control	363.682	41.496	417.143	279.898
Spray	464.344	54.171	549.184	423.020
Immersion	520.233	46.601	568.163	434.286

Table 4: Student t-test analysis of compressive strength tested after (48) hours

	P-value	**Significance**
Control-Spray	0.00246	H.S.
Control-Immersion	0.00002	H.S.
Spray-Immersion	0.06076	N.S.

Table 5: T-test analysis between the means of each group specimens tested after (24) hours and (48) hours.

	P-value	**Significance**
Control (24)- Control (48)	0.00589	H.S.
Spray (24)- Spray (48)	0.00002	H.S.
Immersion (24)-Immersion (48)	0.00000	H.S.

Table 6: Descriptive statistical analysis of surface roughness tested after (24) hours

Surface Roughness value in µm tested after (24) hours				
Group	**Mean value**	**S.D.**	**Max. value**	**Min. value**
Control	0.45	0.159	0.78	0.32
Spray	1.49	0.09	1.57	1.30
Immersion	2.50	0.448	3.30	1.83

Table 7: Student t-test analysis of surface roughness tested after (24) hours

	P-value	**Significance**
Control-Spray	0.00000003	H.S.
Control-Immersion	0.000008	H.S.
Spray-Immersion	0.00109	H.S.

Table 8: Descriptive statistical analysis of surface roughness tested after (48) hours

Surface Roughness value in (µm) tested after (48) hours				
Group	**Mean value**	**S.D.**	**Max. value**	**Min. value**
Control	0.56	0.142	0.73	0.37
Spray	1.32	0.306	1.83	0.83
Immersion	3.35	0.309	3.85	2.90

Table 9: Student t-test analysis of surface roughness tested after (48) hours

	P-value	**Significance**
Control-Spray	0.00034	H.S.
Control-Immersion	0.00000002	H.S.
Spray-Immersion	0.00000003	H.S.

Table 10: T-test analysis between the means of each group specimens tested after (24) hours and (48) hours.

	P-value	Significance
Control (24)- Control (48)	0.182	N.S.
Spray (24)- Spray (48)	0.195	N.S.
Immersion (24)-Immersion (48)	0.00167	H.S.

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