Comparative Evaluation of Surface Detail Changes and Compressive Strength of Gypsum Casts and Dies After Immersion in Hypochlorite Solution and Microwave Irradiation – An in Vitro Study

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ABSTRACT

Introduction: Dental impressions contaminated with the microorganisms from patients' saliva and blood can cross infect gypsum casts poured against them and therefore disinfection of gypsum casts through microwave irradiation is currently been used as an alternative to conventional disinfection methods. Aim was to compare the changes in surface detail and compressive strength of gypsum casts brought about by microwave irradiation and immersion in sodium hypochlorite solution respectively.

Material and methods: 60 samples each of Type III and Type IV gypsum were prepared for compressive strength evaluation and divided into 6 groups (control at 1hr, 24hr, microwave irradiation at 1hr, 24hr, and 0.525% sodium hypochlorite with slurry and without slurry immersion at 24hr). 30 samples each were prepared for surface detail evaluation and divided into 3 groups (microwave irradiation at 1hr, 24hr and 0.525% sodium hypochlorite with slurry immersion at 24hr). The compressive strength was evaluated using Instron machine and surface detail evaluated using Motic stereozoom microscope.

Results: Microwave irradiation, if done after one hour of pouring, causes reduction in strength and loss of surface details of Type III and IV gypsum products. The compressive strength of die stone casts immersed in sodium hypochlorite solution with slurry water are increased significantly but there is a significant associated loss of surface details.

Conclusion: In view of the seriousness of the diseases like HIV and hepatitis, it is recommended to use microwave irradiation after 24 hours of air drying to decontaminate the casts prepared by using Type III and Type IV gypsum products till better alternatives are available.

Keywords: gypsum casts, microwave irradiation, sodium hypochlorite, surface details, compressive strength.

INTRODUCTION

Primary and secondary impressions taken in the mouth regularly get contaminated with micr organisms from blood and saliva of patients and that can lead to infections of the casts that are poured from them. Movements of these organisms into dental casts, while setting, have been demonstrated.[1] Some microbes have been shown to remain viable within gypsum cast materials for up to seven days.[2]

This has led to an increased concern for, and attention to, infection control in dental practice.[3] Different methods have been used to disinfect the dental casts. These include immersing the casts in disinfecting solutions, spraying the casts with disinfecting solutions[4,5] using certain chemicals in gympsum while mixing or using a diestone having disinfectant but it was seen that many physical properties like the setting expansion and setting time were affected by using disinfectant incorporated gypsum. It was observed that physical properties such as setting time and setting expansion were affected by incorporating disinfectants into gypsum.[6-7]

Literature has reported the use of microwave irradiation as an alternative.[8,9] It is found out that this method is effective and practical and eliminates cross contamination via the cast because it can be repeated at every stage as and when required.[8,10]

Present study was undertaken to evaluate the effect of microwave irradiation on surface details reproducibility and compressive strength of type III and type IV gypsum casts and compare that with that seen after immersion in sodium hypochlorite for decontamination.

MATERIAL AND METHODS

The gypsum products subjected to two methods of disinfection included:

Type III dental stone (Kalstone, Kalabhai Dental P Limited, Mumbai) and

Type IV stone (Kalrock, Kalabhai Dental P Limited, Mumbai).

Die fabrication

An aluminium die according to ADA specification No. 25[11] was fabricated to be used as a test die for evaluation of surface detail. The test die had a diameter of 30 mm. 3 parallel lines, x, y, and z, to a depth of 50, 20, and 75 mm respectively, were inscribed for evaluation of surface details. For measurement of compressive strength an aluminium split mould die with guide screws was machine milled. It had 3 compartments for sample preparation, each with 40mm length and 20 mm diameter, according to ANSI /ADA specification No. 25.

Mixing and pouring of gypsum samples

The gypsum products were mixed according to manufacturer's instructions.

The casts were allowed to set for 1 hour at room temperature. The casts that were to be checked after 24 hours were removed from the die and allowed to air dry for 24 hours.

Disinfection using microwave irradiation and sodium hypochlorite immersion

(i) Method for Microwave irradiation: The prepared samples of the microwave irradiation group were kept in the microwave oven and timer set to 3 minutes at full power of 900 Watts and

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2450 MHz (Onida power convection microwave).

(ii) Method for sodium hypochlorite immersion - The samples prepared for the sodium hypochlorite group were immersed in 0.525% solution of freshly prepared sodium hypochlorite in slurry water for 10 minutes in separate boxes which had an air tight lid. The samples were then washed thoroughly under running tap water and dried on table top at room temperature for 24 hours and then subjected to the tests.

Sample preparation for surface detail evaluation

To retain the poured dental stone, a collar was fabricated with elastic material (Impregum Penta Soft Polyether Impression Material; 3M ESPE, St. Paul, Minn) to box the test die.

30 samples, thus prepared for each type of gypsum product were classified into 3 groups as follows:

- Group 1 (Microwave irradiation). Ten samples were tested at 1 hour.
- Group 2 (Microwave irradiation). Ten samples were tested at 24 hours.
- Group 3 (Immersion in 0.525% sodium hypochlorite and slurry solution for 10 min). Ten samples were tested at 24 hours.

Sample preparation for compressive strength evaluation

The split metal mold were filled with dental stone under mechanical vibration as previously described and covered on top and bottom with glass slabs to ensure parallel sides. 120 cylindrical test samples were allowed to set for 1 hour and then retrieved.

The samples prepared were classified into six groups each as follows:

- Group 1 (control). Ten samples each were tested at 1 hour.
- Group 2 (control). Ten samples each were tested at 24 hours.
- Group 3 (Microwave irradiation). Ten samples were tested at 1 hour.
- Group 4 (Microwave irradiation). Ten samples were tested at 24 hours.
- Group 5 (Immersion in 0.525% sodium hypochlorite and slurry solution for 10 min). Ten samples were tested at 24 hours.
- Group 6 (Immersion in 0.525% sodium hypochlorite solution only for 10 min). Ten samples were tested at 24 hours.

Compressive strength evaluation

The compressive strength was tested with an Instron universal testing machine (Instron Corp.,Canton, Mass.) with a 10kg load cell at a crosshead speed of 0.05cm/min. The samples were placed on the platform and the load applied. The samples were then crushed between the load and the platform. The results obtained were recorded in MPa (Figure-1).

Surface detail evaluation

The casts were examined under low angle light at X10 magnification with a stereo zoom microscope (Motic® type 102 M Stereozoom microscope, Vancouver, Canada) for the entirety (continuity) of the 0.05-mm-wide line. Revised ANSI/ADA specification No. 25 requires that gypsum products reproduce a line of 0.05 mm in width when tested at a specific consistency. The reproduction of a 0.05-mm-wide line on the test casts was used for surface detail evaluation. The test casts that did not reproduce the entire length of the 0.05-mm-wide line were discarded. The casts were evaluated based on the graded scoring system with rating values of 1 through 4 (Figure-2). Same investigator performed the evaluation of all the casts.

- Rating 1 indicated a well-defined, sharp continuous line
- Rating 2 indicated a continuous line, but with some loss of sharpness
- Rating 3 indicated a loss of continuity of the line
- Rating 4 indicated complete obliteration of the line.

RESULTS

Observations made on compressive strength of dental stone (Type III gypsum product) and die stone (Type IV gypsum product) were statistically evaluated using independent t test for one hour groups and one way ANOVA multiple comparison Tukey HSD post hoc test for 24 hours groups. For statistical analysis of surface details, chi-square test was used to determine the significance of relationship between the numbers of scores. All computations were conducted in the SPSS (Statistical package for social sciences) software (version 11.5).

Compressive strength

Table–1 shows the readings of compressive strength evaluation after microwave irradiation and hypochlorite immersion of type III and IV dental stone.

Type III stone samples: At one hour interval, the mean compressive strength of microwave irradiation group was significantly lower compared to control group ($p<0.05$).

At 24 hours, compressive strength values showed no significant difference between control group, microwave irradiated group and hypochlorite immersion group ($p>0.05$ and $p>0.05$ respectively). However, a significant difference ($p<0.05$) in compressive strength was observed between the

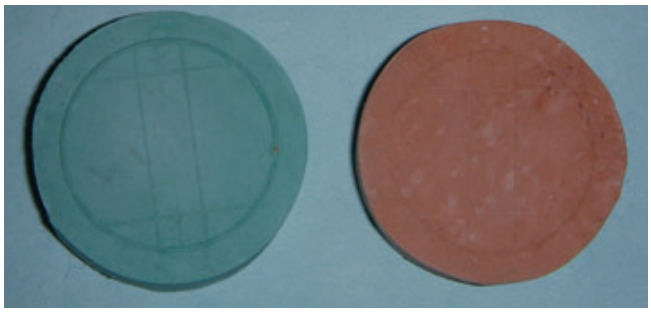

Figure-1: Sample for surface detail evaluation

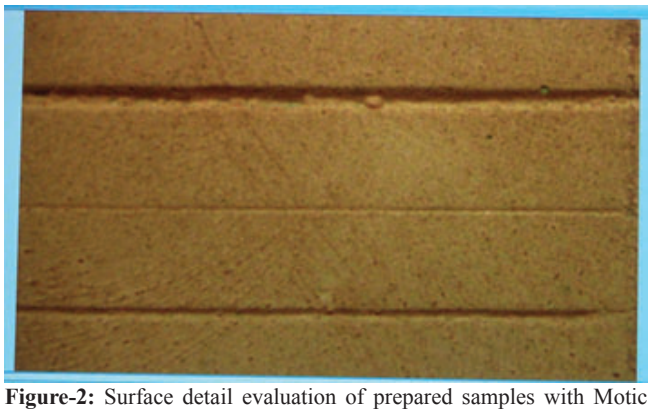

Figure-2: Surface detail evaluation of prepared samples with Motic type 102 M stereozoom microscope (Motic stereozoom, Canada)

control group and sodium hypochlorite immersion group without slurry water wherein control group exhibited higher compressive strength. Significant difference in compressive strength was observed between microwave irradiated samples and hypochlorite immersion without slurry ($p< 0.05$).

Type IV die stones: At one hour interval, mean compressive strength of control group was significantly higher as compared to microwave irradiation group ($p<0.05$). Compressive strength values of control group and microwave irradiated samples were not significantly different ($p>0.05$) at 24 hours. However, samples immersed in hypochlorite solution containing slurry showed superior compressive strength ($p<0.05$) where as those immersed in hypochlorite solution without any slurry exhibited inferior compressive strength values in contrast to controls ($P<0.05$)

Samples subjected to microwave irradiation exhibited less resistance to compressive forces in comparison to samples prepared with sodium hypochlorite with slurry water ($p<0.05$). However, samples prepared with sodium hypochlorite solution (containing no slurry) showed inferior compressive strength as compared to microwave irradiated samples ($p>0.001$).

Surface details

Summary of results obtained are presented in Table-2. All the samples of type III and IV gypsum in control group exhibited better surface detail reproduction and were able to clearly reproduce a line of 50µm thick as indicated by 100% score in score 1.

When microwave irradiated after one hour, Type III samples have shown minimum changes in the surface details as noted from the scores obtained which lie mainly between score 1 and 2. With Type IV, microwave irradiation did not cause any change in the surface detail as noted by 90% score in score 1 with these samples. Both did not show much change in the surface detail when subjected to microwave irradiation after 24 hours as is clear from the 90% and 80% score in score 1 respectively. Greater loss of surface detail was observed with samples when subjected to hypochlorite with slurry water as the scores obtained by most of these samples varied from 3 to 4.

DISCUSSION

Since autoclaving process would be damaging to the dental cast, methods to disinfect dental casts were suggested by American Dental Association (ADA) and Centers for Disease Control and Prevention that included immersion and spraying. It is imperative that all the procedures do not effect the physical properties of the dental casts.[12]

Hypochlorite has held a predominant position as a reliable disinfectant because it has a broad antimicrobial spectrum, rapid bactericidal action, reasonable persistence in treated potable water, ease of use, solubility in water, relative stability both in its concentrated form and at its used dilution, relative nontoxicity to humans at used concentrations, lack of poisonous residues (reduced predominantly to chloride as a result of its oxidizing action on inorganic and organic compounds), action as a deodorizer, colorless, nonflammable, non-staining, and also low cost.

Immersion of the casts in disinfectant solution is effective and is the most widely employed disinfection procedure compared to spray technique. However, it was observed that the immersion process affects the surface quality of the casts/dies. Rudd et al[13] showed altered surface properties on immersing a stone cast in tap water for 15 min. Kumar et al[14] observed increase in linear dimension and decreased hardness in Type III dental stone specimens when immersed in hypochlorite solution.

Inability to assume that every impression presented to the laboratory has been disinfected completely, inability of the spray technique to completely disinfect the casts and the potentially damaging effects of immersion technique prompted the use of other techniques of disinfecting the dental casts/dies with minimum damage.[12]

Studies have been undertaken to evaluate the disinfection potential of microwave irradiation of dental casts.[6-10]

Microwaves comprise the band of electromagnetic spectrum extending from the frequency of 300 MHz to 3,00,000 MHz. Most commercial microwave ovens operate at 2450 MHz. Microwaves are generated by magnetron and propagated in a strong line along the wave guide(dominant mode). In the materials cintaing water microwaves are absorbed. However, microwave irradiation was found to cause enlargement of the

Description	1Hr Control	1Hr Microwave	24Hr Control	24Hr Microwave	24Hr Hypochlorite with slurry	24Hr hypochlorite without slurry
Dental Stone						
Mean (MPa)	18.57	15.93	23.95	23.25	25.15	20.08
S.D	1.16	3.03	2.18	1.34	1.09	2.05
Die Stone						
Mean (MPa)	24.04	16.80	33.81	33.49	38.24	29.43
S.D	3.04	1.45	1.86	1.75	1.52	3.93

Table–1: Readings of compressive strength evaluation after microwave irradiation and hypochlorite immersion of dental stone and die stone

Description	Dental Stone				Die stone			
	1	2	3	4	1	2	3	4
1Hr Control	10	-	-	-	10	-	-	-
1Hr Microwave	4	5	1	-	9	1	-	-
24Hr Control	10	-	-	-	10	-	-	-
24Hr Microwave	9	1	-	-	8	2	-	-
24Hr Hypochlorite with slurry	-	3	4	3	-	3	4	3

Table–2: Scores for surface detail evaluated after microwave irradiation and hypochlorite immersion of the dental stone and die stone

pores on the surface of the cast because of rapid loss of steam which may have an influence on the mechanical characteristics and reproducibility of the surface details.[15]

Since fabrication of a dental prosthesis requires the dental cast to undergo various laboratory procedures,the most important are the strength of the dental cast and its ability to retain the surface details,.

Effect of microwave irradiation on compressive strength

It was observed that both Type III and IV gypsum had a decreased compressive strength when subjected to microwave irradiation at one hour. This decrease was more prominent in Type IV as compared to that seen for Type III which is due to the differences in the crystal shape, density, intermeshing and entanglement of dehydrate crystals in the gypsum tested. In Type III, the number of crystal nuclei formed is much smaller and the amount of intermeshing and entanglement is less. Whereas formation of a dense mass with less amount of porosity is seen in type IV. When Type IV gypsum casts are subjected to microwave irradiation, excess water used during mixing, although less compared to Type III, forms steam and creates cracks or porosities while leaving the surface. Because structure of Type IV is dense, the escape of steam creates stress in the material which probably leads to formation of minor cracks in the material. Formation of porosities or micro cracks could be the reason why it failed at low stress values.

Type III gypsum is not as dense and allows easy escape of steam and there by showing little change in compressive strength. Compressive strength of control samples measured at 24 hours is not significantly different from the compressive strength of microwave irradiated specimens. This is understood as most of the excess water would have evaporated from the material with 24 hours. It has also been suggested that microwaves should not be used to disinfect wet casts.

In a study conducted by Leubke and Schneider,[15] it was observed that at 2 hours, there is no significant difference in compressive strength of Type III dental stone dried in microwave oven when compared with the air dried stone.

Leubke and Schneider[15] also observed that die stones were physically changed by microwave drying because of the appearance of cracks and holes on the surface.

Leung RL et al[1] advocated setting the oven at lowest power level. In another study, highest power level resulted in a decrease in the compressive strength of Type IV die stone was found by Tuncer et al.[16]

Effect of microwave irradiation on surface detail reproduction

Microwave irradiation of samples at the end of one hour resulted in changes in surface details in about 60% samples. However, this effect was not significant when the samples were irradiated with microwaves at the end of 24 hours. The loss of surface details at one hour was due porosity or micro cracks formed by the steam during microwave irradiation.

Effect of hypochlorite and slurry on compressive strength

The use of clear slurry water (saturated calcium sulphate) has been used for soaking dental casts with no damage to the surface.[17] In the present study, the effect of sodium hypochlorite disinfectant was evaluated in the presence or absence of slurry water on the compressive strength.

At 24 hours, immersion in sodium hypochlorite (0.525%) with slurry water did not decrease compressive strength of type III samples significantly. Instead, for Type IV stone there was a significant increase in compressive strength. Immersion in sodium hypochlorite (0.525%) without slurry water decreased compressive strengths significantly, more in comparison to control specimens that were air dried. Our observation support what Sarma and Neiman[18] had noted.

Although sodium hypochlorite immersion disinfects the cast, the effect it has on the physical properties is a concern. The assumption is that sodium ions from the hypochlorite interfere with structure and strength of the gypsum which contains calcium in its structure. Presence of slurry may not allow any further degradation or solubilisation of samples.

Ivonovski et al[19] reported a decrease in compressive strength with the addition of sodium hypochlorite to the stone during mixing. Abdelaziz et al[20] found a reduction in compressive and tensile strengths both, in Type III and IV when combined with sodium hypochlorite. However, same materials when immersed in same concentration of hypochlorite solution containing slurry, the changes in the compressive strength were not significant.

Effect of hypochlorite and slurry on the surface details

Immersion in hypochlorite solution with slurry caused significant loss of surface detail which can be due to the ability of sodium hypochlorite to dissolve the surface of the cast materials during immersion. During the setting process, fine crystals of gypsum precipitate are left behind to anchor larger crystals as the last molecules of water leave the surface of the dental casts. When water or any solution is reintroduced onto the surface, the small crystals are the first ones to dissolve. This explains the loss of surface details after immersion disinfection.[21]

Our observations are contrary to the study done by Bass et al[17] who compared the effects of immersion disinfection of casts in a mixture of sodium hypochlorite and slurry water for 30-minute and 1-hour intervals. They reported no difference in the quality of the cast surface when submerged in the disinfectant slurry and slurry water.

CONCLUSION

It can be concluded that microwave irradiation gypsum products after one hour of pouring reduced the strength but not significant at the end of 24 hours ($p>0.05$).

Considering the consequences of cross infection of the diseases like HIV and hepatitis, we recommend the use of microwave irradiation after 24 hours of air drying to decontaminate the casts and dies till better alternatives are available.

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