ORIGINAL RESEARCH

Effect of Hypochlorites on the Compressive Strength and Surface Hardness of Type V Dental Stone: An *In Vitro* Study

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Abstract

Aim: The study aimed to evaluate the compressive strength and surface hardness of a type V dental stone after hypochlorite disinfection.

Materials and methods: Two types of specimens were made according to the American Dental Association (ADA) specification no. 25 for each wet compressive strength, dry compressive strength, and surface hardness. The specimens were split into three groups with 30 samples each according to the type of disinfection. All specimens were immersed in their respective disinfecting solutions for 30 minutes at room temperature and after removal, they were left to dry for 24 hours at room temperature. Total five cycles of immersion and drying were followed. A compressive strength test was done using a universal testing machine. Wet compressive strength was tested one hour after the last cycle and dry compressive strength was tested 7 days after the last cycle. Surface hardness was measured after 48 hours using Vickers hardness test. The results were statistically analyzed.

Results: There was a statistical difference between the calcium hypochlorite and sodium hypochlorite groups for both dry and wet compressive strength. The mean wet compressive strength of calcium hypochlorite was higher when compared to the sodium hypochlorite group and it was statistically significant ($p = 0.042$). The results were similar and statistically significant ($p = 0.003$) for dry compressive strength. When the mean surface hardness of the sodium hypochlorite (A_s) group was compared to calcium hypochlorite the results were highly significant ($p = 0.0001$) with the mean surface hardness of the calcium hypochlorite group more than the sodium hypochlorite group.

Conclusion: Calcium hypochlorite used as a disinfectant showed better compressive strength and surface hardness when compared to sodium hypochlorite as a disinfectant.

Clinical significance: Dental casts poured in the contaminated impressions which might not be disinfected at all or properly. They also come in contact with the prosthesis that might be tried inside the patient's mouth and sent to a lab for corrections without disinfecting the cast causing cross-contamination between patients, dentists, and laboratory personnel. However, immersion disinfection with sodium or calcium hypochlorite might affect important properties of the cast. Any negative effect on the mechanical or physical properties of the cast will affect the final outcome of the prosthesis.

Keywords: Compressive strength, Dental stone, Disinfection, Hypochlorite, Surface hardness.

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Introduction

Oral healthcare workers face the risk of exposure to infection from communicable diseases daily due to direct or indirect contact with patients' oral tissues via materials used in dentistry. Salivary and blood contamination of impressions augments the need for antimicrobial disinfection.[1,2] Hydrophobicity or hydrophilicity of impression materials coupled with a lack of knowledge to overcome such barriers to disinfection could further vitiate transmission to laboratory personnel. Gypsum casts made from such impressions harbor pathogenic microbes, causing possible cross-contamination between patients and dentists.[1–3] Gypsum casts are transferred numerous times between dental laboratories and clinics during fabrication of prosthesis wherein the trial of the prosthesis may be done inside the oral cavity of the patient and it is kept back on the cast. This might be repeated multiple times. Hence, attention is directed towards cast disinfection.[4]

Literature abounds with methods used to disinfect dental casts. The American Dental Association (ADA) and Center for Disease Control (CDC) have suggested immersion disinfection of dental casts. Sodium hypochlorite and calcium hypochlorite have proven to be used as disinfectants in arious studies.[5–7] For immersion the

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disinfectant can be incorporated into water saturated with calcium sulfate slurry as suggested by various authors since it does not cause damage to the surface of the casts.[8,9] In fixed prosthodontics, dental casts and die materials are required to precisely reproduce the positive replica from the impressions, accurately producing all the fine details while maintaining dimensional stability and abrasion resistance.[6] The different die materials used are type IV gypsum, type V, epoxy resin, polyurethane resins, resin-modified gypsum, electroformed dies, etc. The most commonly used die materials are gypsum-based type IV and type V. Type V dental strength has high strength and high expansion.[10,11] Few of the criteria incorporated to select the stone includes mechanical properties such as compressive strength and surface hardness.[11–14] The compressive strength of the set dental stone is important because, if it is low, it shows easy fracture of the isolated tooth during removal from some impression materials.[3] Surface hardness of the dental stone is important as, if it is reduced, then at the time of preparation on the cast it can lead to abrasion and distortion of the surface which will hinder the precision fit of the prosthesis.[15] So, it becomes important to see if there is any undesired effect of disinfection on the mechanical properties of gypsum products. This study aims to evaluate the compressive strength and surface hardness of type V dental stone after immersion into two different disinfectant solutions, to observe and compare the differences between two disinfectants for both the properties tested.

Materials and Methods

The present study was conducted in the Department of Prosthodontics, Coorg Institute of Dental Sciences, Virajpet, Karnataka, India. Ethical clearance was taken from the Institutional Review Board for the same. Two different types of test specimens were made according to ADA specification no. 25 one for assessment of compressive strength and the other for the surface hardness. For the compressive strength test a split metal mold of dimension 20 × 40 mm was made.[16] For surface hardness a split metal mold of dimension 30 × 15 × 15 mm was made.[11] In a clean rubber bowl type V dental stone (Denflo-Hx, PrevestDenpro Limited, Jammu, India) was mixed as mentioned by the manufacturer. The mix was poured into the respective molds with a glass slab placed below the mold while it was kept on the vibrator (Dental Vibrator, Sirio Dental SRL, Itlay) to eliminate bubbles. Total 60 specimens were made for the compressive strength test (Fig. 1) and 30 specimens for the surface hardness test (Fig. 2).

The specimens were split into three groups A, B, and C with 30 samples each according to the type of disinfection of which group A was immersion in a slurry with 0.525% sodium hypochlorite (SD Fine-Chem Limited, Mumbai, India), group B was immersion in a slurry with 0.5% calcium hypochlorite (SD Fine-Chem Limited, Mumbai, India) and group C was a control group with immersion in slurry, a supernatant solution of calcium sulfate in distilled water which is prepared by keeping set dental stone pieces in a glass container filled with distilled water for 48 hours. These were further divided into three subgroups with 10 samples each, i.e.,

A_w—Specimens immersed in sodium hypochlorite for wet compressive strength test,

A_d—Specimens immersed in sodium hypochlorite for dry compressive strength,

A_s—Specimens immersed in sodium hypochlorite for surface hardness test,

B_w—Specimens immersed in calcium hypochlorite for wet compressive strength test,

B_d—Specimens immersed in sodium hypochlorite for dry compressive strength,

B_s—Specimens immersed in sodium hypochlorite for surface hardness test,

C_w—Specimens immersed in slurry for wet compressive strength test,

Fig. 2: Specimens for testing surface hardness

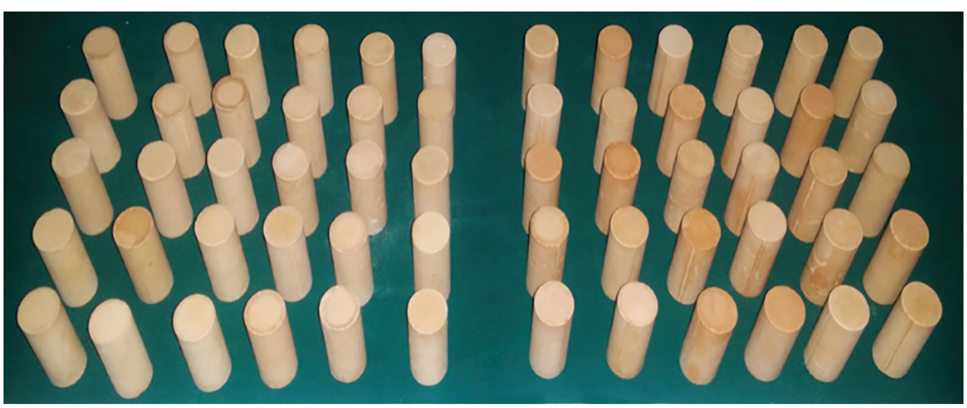

Fig. 1: Specimens for testing compressive strength

C_d—Specimens immersed in slurry for dry compressive strength,

C_s—Specimens immersed in slurry for the surface hardness test.

All the specimens were immersed in their respective disinfecting solutions for 30 minutes at room temperature. Specimens were retrieved after 30 minutes and allowed to air dry for 24 hours at room temperature. The process of submerging and drying at room temperature conditions was repeated five times considering the maximum number of immersions required in case of fixed dental prosthesis. The specimens were left to air dry at room temperature for 24 hours between cycles.

Compressive Strength Test

For wet compressive strength after the last cycle of immersion, the specimen was tested after 1 hour. For dry compressive strength, the test was done after 7 days. The compressive strength of the specimens was measured using the universal testing machine. The specimens were positioned vertically on the universal testing machine and pulverized at a crosshead speed of 1.0 mm/minute (Fig. 3). It was calculated with the formula:

$C = P/\pi r^2$

where C is compressive strength (Mpa),

P is the load to failure,

r is the radius of the specimen.

Surface Hardness Test

Surface hardness was measured 48 hours after the last immersion cycle using Vickers hardness test (Vm-50, Fie, Fuel Instruments And Engineers Private Limited, Maharashtra, India) Indentations were made on the specimens at three points which were at equal distance from each other (Fig. 4). The results were calculated according to the area of indentation made using the formula:

$VHN = 1.854 \times P/d^2$,

where P is the load applied,

d is the length of the long axis of the diagonal.

Statistical Analysis

Statistical analysis was done using SPSS version 17. To compare the means of precisely two group's independent sample t-test was used. A p-value of <0.05 was considered statistically significant.

Fig. 3: Specimens for testing the compressive strength placed vertically and crushed at 1.0 mm/minute

Fig. 4: Indentations made on the specimens with the indenter to test the surface hardness

Results

The mean wet compressive strength of the control (C_w) group was greater compared to the sodium hypochlorite (A_w) group and was statistically significant ($p = 0.004$) when compared. The comparison of mean wet compressive strength between the control (C_w) group and the calcium hypochlorite (B_w) group was statistically nonsignificant ($p = 0.213$). The mean dry compressive strength of the control group (C_d) was found to be greater than the sodium hypochlorite (A_d) group and was statistically significant ($p = 0.001$). However, the mean dry compressive strength of the control group (C_d) was found to be statistically nonsignificant when compared with the calcium hypochlorite (B_d) group. The surface hardness of type V dental stone after immersion into 0.525% sodium hypochlorite and 0.5% calcium hypochlorite disinfectant solutions were evaluated. It was found that the mean surface hardness of the control (C_s) group was greater than sodium hypochlorite (A_s) these results were statistically highly significant ($p = 0.000$). When the mean surface hardness of the control (C_s) group was compared with the calcium hypochlorite (B_s) group it was also found to be statistically highly significant ($p = 0.0001$). The mean wet compressive strength of calcium hypochlorite (B_w) was higher when compared to the sodium hypochlorite (A_w) group and it was statistically significant ($p = 0.042$) as seen in Table 1 and (Fig. 5).

The results were similar and statistically significant ($p = 0.003$) for dry compressive strength with mean dry compressive strength of calcium hypochlorite group (B_d) higher than mean dry compressive strength of sodium Hypochlorite group (A_d) as seen in (Table 2) and (Fig. 5). When the mean surface hardness of the sodium hypochlorite (A_s) group was compared to calcium hypochlorite (B_s) the results were highly significant ($p = 0.0001$) with the mean surface hardness of B_s group more than (A_s) as shown in (Table 3) and (Fig. 6).

Discussion

According to evidence in the current literature, dentists are amongst the most exposed personnel to the COVID-19 contagium. The sudden pandemic breakout proved to be threatening and has set on the necessity to give special importance to the implementation of precautionary protocols in dental practice.[17] In the field of dentistry

Table 1: Comparison of mean wet compressive strength between sodium hypochlorite and calcium hypochlorite using independent sample *t*-test

Group	*Mean (Mpa)*	*SD*	*t value*	*p value*	*Significance*
Sodium hypochlorite (A_w)	15.86	1.31	2.194	0.042	S
Calcium hypochlorite (B_w)	17.11	1.23			

p <0.05 was considered statistically significant; S, significant

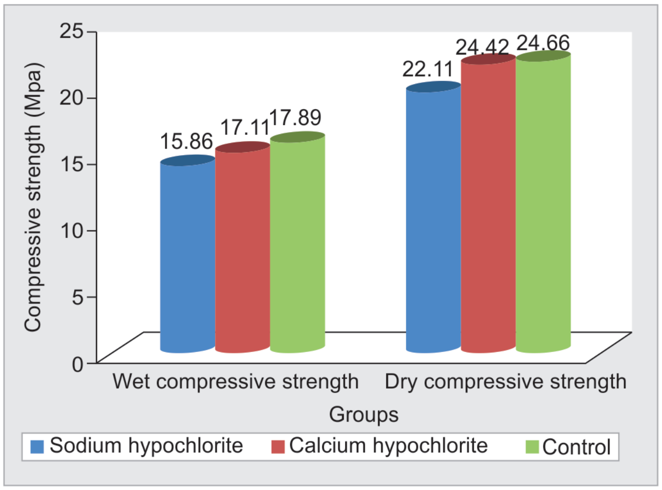

Fig. 5: Comparison of mean wet and dry compressive strength between control, sodium hypochlorite, and calcium hypochlorite groups

Table 2: Comparison of mean dry compressive strength between sodium hypochlorite and calcium hypochlorite using independent sample *t*-test

Group	*Mean (Mpa)*	*SD*	*t value*	*p value*	*Significance*
Sodium hypochlorite (A_d)	22.11	0.91	3.480	0.003	S
Calcium hypochlorite (B_d)	24.42	1.88			

p <0.05 was considered statistically significant; S, significant

Table 3: Comparison of mean surface hardness between sodium hypochlorite and calcium hypochlorite using independent sample *t*-test

Group	*Mean (VHN)*	*SD*	*t value*	*p value*	*Significance*
Sodium hypochlorite (A_s)	14.36	0.98	13.089	0.0001	HS
Calcium hypochlorite (B_s)	19.04	0.54			

p <0.05 was considered statistically significant; HS, highly significant

there has been a high concern related to the spread of infection and cross-contamination from clinics to laboratories as the dentists and technicians come in direct or indirect contact respectively. The wide array of armamentarium and varied composition of impression materials makes it a challenge to disinfect or sterilize these in a predictable manner. Due to this, attention was directed towards the casts sterilization or disinfection.[2,3] Casts are considered important as they represent clinical situations and aid in the diagnosis, treatment planning as well as fabrication of the prostheses.[9]

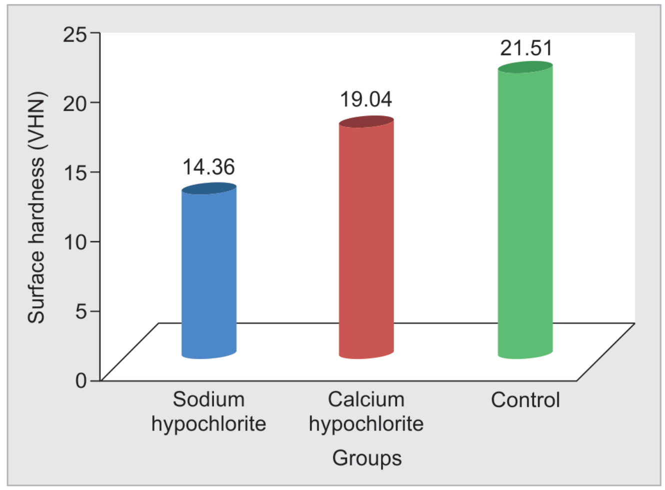

Fig. 6: Comparison of mean surface hardness between control, sodium hypochlorite, and calcium hypochlorite groups

In fixed and removable prosthodontics type V dental stone is commonly used for fabrication of the cast over which the prosthesis could be made. The swift progress of precision casting technology and the development of the theory of occlusion, demands accuracy in the order of microns. Such precise accuracy depends on all the steps of prosthesis fabrication including dental cast or dies which play a crucial role in indirect restorations.[18] Dies are exposed to substantial physical abuse when retrieved from impressions, replicated to make refractory casts, or when dental restorations are seated. It is essential that these materials should possess certain properties like high compressive strength, surface hardness, minimal setting expansion, etc.[14,19]

Mitchell et al.[4] did a study on the casts contaminated by saliva and found that the bacterial contamination of these casts doesn't decrease with time, but however may be reduced by using disinfection.[9] The use of infection control procedures in the dental setup has been endorsed by the CDC andADA.[20,21] ADA council on dental materials has given certain guidelines for the acceptable methods of disinfection for disinfection of dental stone casts in 1988 and 1996.[22,23] According to the guidelines spray and immersion may be used for disinfection with hypochlorite or iodophor. The spray disinfection is ineffective as it has an inability to completely cover the surface and does depend on undercut areas, angle of the spray dispenser and interproximal surfaces may be missed in the application.[6] Also the porosity of the stone casts necessitates that the surface is completely saturated for the disinfectant to be effective, which is hard to attain and maintain by spray disinfection.[6,7] So, in the present study immersion disinfection was used.

The two disinfectants used in this study were hypochlorites; sodium hypochlorite 0.525% as advised by ADA[22] and also calcium hypochlorite 0.5% which has been used in previous studies.[6,7] According to a review by Kampf et al.[24] there are various studies proving the effectiveness of sodium hypochlorite disinfectant on the coronavirus which does remain on the surface of inanimate surface and is also expected to be effective on the novel coronavirus (SARS-CoV-2). In the present study, an immersion cycle of 5 days was used similar to a previous study done by Michael et al.[16] Casts and die materials could be subject to an average of five times of exchange between dental and laboratory personnel from initial impression appointments through the delivery of the prosthesis. Thus, a five-cycle sequence of disinfection was selected for the number of applications required in the fabrication process. The duration of immersion was 30 minutes which has been proven to be effective in the previous studies and has been reported by ADA and CDC.[23] In a study done by previous authors sodium hypochlorite disinfectant solution was used by diluting it to 0.525% concentration with distilled water and reported effective antimicrobial activity when used on dental stone casts for a duration of at least 30 minutes.[5] The surface loss and roughness increase with time when the dental stone casts are immersed in water. From the clinical standpoint, it has been concluded that whenever required the casts should be soaked in slurry water which showed no detrimental effects.[9] In the present *in vitro* study wet compressive strength, dry compressive strength, and surface hardness weretested. Specimens were tested for wet compressive strength 1 hour after the last immersion cycle. Whereas for dry compressive strength, the specimens were tested after 7 days as suggested in the study done by Abdelaziz et al.[3] The dry strength is affected by the free water content of the hardened product. Due to this reason two strength properties of gypsum were tested: the wet strength (also known as green strength) and the dry strength. Once the hydration of hemihydrate is complete, the excess water that is present in the set gypsum gives the wet strength of the specimen.[25] When excess water in the specimen is removed by drying, the strength obtained is the dry strength. Dry strength may be high as the wet strength by two or more times. Consequently, the distinction between the two is considered to be important.[25] Surface hardness of gypsum materials is related generally to their compressive strength. The high compressive strength of the hardened mass correlates to high surface hardness. However, the surface hardness increases at a rapid rate than the compressive strength because the surface of the hardened mass reaches a dry state earlier than the inner portion of the mass.[26] Also the surface hardness will be affected more than the compressive strength.

The results for the compressive strength were similar to the study done by Abdelaziz et al.,[2] who claimed that when type V dental stone was mixed with an aqueous solution of 0.525% sodium hypochlorite it resulted in reduced compressive strength. In another study done by Breault et al.,[27] the compressive strength increased when sodium hypochlorite was added unlike the results of the present study. In a study by Twomey et al.,[6] it was found that the addition of calcium hypochlorite reduces the compressive strength, the results were similar to the present study. In this study, it was found that both compressive strength and surface hardness of the control samples was more when compared to the sodium hypochlorite and calcium hypochlorite group. In the control group since no disinfectant was used; there was no erosion of the surfaces of the sample which occurred in the other test groups. The surface hardness of the control was quite high in comparison to the disinfectant group. This might be because the surface of the control group specimens was least affected, unlike the disinfectant group which was found to be rougher on visual inspection after the last cycle of immersion. The slurry is a saturated solution of calcium sulfate that contains both Ca^{2+} and SO_4^{2-}. There is no dissolution or negligible dissolution of the cast in the slurry.[25,28] Due to this process there might be no appreciable changes on the surface of the specimens. Also, the compressive strength and surface hardness are found to be interrelated to each other. The compressive strength is affected by porosity. As stone is porous, when it is treated with sodium hypochlorite which is a strong oxidizing agent there may be an ionic interaction. When dissolved in water sodium hypochlorite dissociates into highly active hypochlorous acid ($HOCl^-$) and less active hypochlorite (OCl^-) ions. Na^+ ions may react with sulfate, or it may form abond with negatively charged molecules or ionic interactions can be expected. Calcium sulfate dihydrate is hygroscopic and soluble in water at a rate of 2.05 g/L at 25°C.[26] Solubility also depends on the calcium sulfate compounds in multicomponent aqueous solutions and in water. The solubility of calcium sulfate dihydrate amounts to the sum of the associated calcium sulfate neutral species and the molalities of the free calcium ion, Ca^{2+}.[29] The free sodium ions available after the dissociation of sodium hypochlorite may react with sulfate molecules from calcium sulfate so more sulfate molecules are released than the normal process due to which the material becomes rough and the hardness and compressive strength are reduced too. Whereas in the case of calcium hypochlorite the dissociation is less, it is only about 21% at 25°C.[30] The calcium ions released by both the materials (calcium hypochlorite and calcium sulfate) may not react and dissociation is also not affected. Hence, materials immersed in calcium hypochlorite solution may not have much effect in any of the two properties studied

Within the limitations of this study, 0.5% calcium hypochlorite used as a disinfectant showed better compressive strength and surface hardness when compared to 0.525% sodium hypochlorite as a disinfectant. In this study, calcium hypochlorite was used for immersion disinfection and compared with sodium hypochlorite which has not been done in any previous study. However, further studies are required to check various other properties of dental stone, like linear expansion, surface roughness, and dimensional accuracy. Also, studies should be done to compare with other disinfectants and other methods of disinfection.

Conclusion

Within the limitations of the present study, it was concluded that when the control group was compared to either of the disinfection groups, it was found that the wet, as well as dry compressive strength, was significantly reduced for sodium hypochlorite. When the control group was compared to either of the disinfectant groups the surface hardness for both the groups was reduced significantly. However, among both the disinfectant groups the surface hardness, wet and dry compressive strength for the specimens immersed in calcium hypochlorite disinfectant was better when compared to sodium hypochlorite disinfectant. So, calcium hypochlorite can be considered as a better alternative option for immersion disinfection of the dental casts.

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