A Comparative Study of the Effect of Different Disinfectant Solutions on the Compressive Strength of Type III Gypsum

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Aim: To investigate and compare the effect on compressive strength after incorporation of disinfecting solutions (sodium hypochlorite and povidone iodine) to commonly available type III dental stone. Materials and Methods: A total of 90 dental stone samples of 20 × 40 mm were made. The standardized samples were fabricated according to the ADA specification no. 25 using custom-made silicon mould and divided into 3 groups. Group A, type III gypsum was incorporated into distilled water; Group B, sodium hypochlorite (3%) was incorporated into distilled water in the ratio of 1:10 concentration according to ADA specification; and Group C, povidone iodine (3%) was incorporated into distilled water. The mix was carefully vibrated into the silicone mould and allowed to set. The specimens were subjected to compressive load after 1 and 24 h from the time of mixing using an Universal Instron testing machine. The result obtained were tabulated and subjected to statistical analysis using two-way analysis of variance tests. Results: This study showed that incorporating the disinfecting solutions like sodium hypochlorite and povidone iodine decreases the compressive strength of type III dental stone. The effect of decreasing compressive strength on type III gypsum product is seen more in povidone iodine when compared to sodium hypochlorite disinfecting solution. Conclusion: Incorporation of sodium hypochlorite and povidone iodine disinfecting solutions is not an encouraging method as it reduces the compressive strength of type III gypsum product.

Keywords: Dental stone, povidone iodine, sodium hypochlorite, sterilization

INTRODUCTION

Gypsum and its products are used since centuries in various fields. In dentistry, it is mainly used to make casts and as an adjunct to various dental laboratory operations that are involved in the fabrication of various oral and maxillofacial prostheses. The stone models obtained from the impressions, which are susceptible for contamination, can generate a contaminated gypsum cast, leading to cross contamination between the dental personnel and the patient. Thus, it is always safe to follow the protocol of disinfection at every possible stage of fabrication of prosthesis to avoid cross contamination. Present guidelines recommend rinsing the impression under running water to remove blood and saliva, followed by spray or immersion disinfection at varying lengths of time.[1] Most reports have found that dimensional stability is not significantly sacrificed with immersion techniques. However, problems may develop with the hydrocolloid and polyether materials because of imbibition of water. The Occupational Safety and Health Administration (OSHA) guidelines and the American Dental Association (ADA) have

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suggested methods for disinfection, such as immersion in or spraying with a disinfectant.\[1\] ADA issued guidelines for disinfecting impressions in 1988, revised in 1991 and 1996. These guidelines recommend using an ADA-accepted spray or immersion disinfectant, depending on the material and for the manufacturer recommended contact time of 30 min.\[2\] The major disadvantage of these techniques is deterioration of surface quality and inability of surface disinfectant material to penetrate the cast, which might result in the core of the model being contaminated.\[3\] So, an alternative method should be opted, wherein the whole bulk of the cast can be disinfected. One of the techniques involves incorporation of disinfectant into gauging/mixing water before addition of dental stone, which does not require extra laboratory time.\[1,3,4\] Although, the various studies have been conducted to evaluate the physical properties of cast gypsum after incorporation of disinfectants, spraying method and immersion method, none have compared the compressive strength after incorporation of sodium hypochlorite (NaOCl) and povidone–iodine solution as mixing solutions.

Terbrock et al. examined various sterilizing methods during several of the dental cast production, finding that an addition of 5.25% NaOCl, as little as 25% by volume to the liquid produces a biologically safe dental cast. Robert et al. showed that when chloramine-T was activated with water, which was similar to a dilute form of NaOCl, which has bactericidal effect concluding that, it is a viable method for disinfecting dental impressions and dental stone casts.\[5\] Povidone–iodine, one of the complexes of iodine with polyvinylpyrrolidone, is now widely used for surgical scrub and skin disinfection in hospitals. The bactericidal action of povidone–iodine is the result of free iodine released from the polyvinylpyrrolidone–povidone complex. This free iodine causes plasmolysis of the bacterial cells, thus killing the bacteria. In povidone–iodine solution, a small amount of free iodine is constantly released, and it remains in equilibrium with the complex until the available iodine is exhausted.\[6\] The type III gypsum product is one among the popularly used gypsum product for pouring of diagnostic casts. Keeping in mind, the safe disinfection protocol, it was decided to investigate and compare the compressive strength of common commercially available type III gypsum product after incorporating NaOCl and povidone–iodine into distilled water after 1 h and after 24 h intervals from the time of mixing.

**Materials and Methods**

The following materials were used: dental stone (Gyprock) Lot no. 9/12, December 2010, disinfectants—sodium hypochlorite, manufactured date: November 2010 (Venson India, Bangalore, India) and povidone–iodine, manufactured date October 2010 (MEDI SWISS India, Bangalore, India). In addition, silicone-duplicating material—Wirosil (BEGO Bremen, Germany), distilled water, graduated measuring jar, rubber bowl, plaster mixing spatula, glass plate, vacuum mixer, electronic weighing machine, metal die—40 × 20 mm, and Instron Universal Testing Machine-A 308 (Manipal, India) were used.

**Figure 1:** Six cylindrical metal dies with dimensions of 20 mm in diameter and 40 mm height were fabricated as per the American Dental Association specification number 25

**Figure 2:** The dies were fixed on a glass slab using adhesive taking care that all dies were equally distributed in a ring (receptacle) of 45 mm height and 100 mm diameter
This in vitro study was conducted to compare the commercially available type III dental stone and to evaluate the compressive strength after incorporating NaOCl and povidone–iodine disinfecting solutions into gauging water and a control group using distilled water without any disinfectants.

The commercially available type III dental stone (Gyprock) and two commercially available disinfectant solutions, NaOCl and povidone–iodine, were used in this study. Six cylindrical metal dies with dimensions of 20 mm in diameter and 40 mm height were fabricated as per ADA specification number 25 [Figure 1].

The dies were fixed on a glass slab using adhesive, taking care that all dies were equally distributed in a ring (receptacle) of 45 mm height and 100 mm diameter [Figure 2]. In addition, silicone-duplicating material was mixed with a ratio of 1:1 as per manufacturer’s directions and was poured into the receptacle taking care that no air bubbles were trapped around the dies [Figure 3]. Mold with the dies was left for 40 min at room temperature for complete polymerization of the material. Thereafter, the metal cylinders were removed from the mold [Figure 4]. Gauging water with NaOCl was prepared by adding 10 mL 3% NaOCl into 100 mL distilled water in the ratio of 1:10 concentration according to ADA specification. Gauging water with povidone–iodine was prepared by adding 10 mL 2% iodine solution into 100 mL distilled water in the ratio of 1:10 concentration. A total of 180 specimens were made as follows:

- Group A and I: Dental stone (without disinfectant) (60 samples)
- Group B and II: Dental stone with NaOCl (60 samples)
- Group C and III: Dental stone with povidone–iodine (60 samples)

For fabrication of test specimens, dental stone powder was weighed on an electronic balance. The water:powder ratio was strictly followed according to the manufacturer’s instructions (28 mL/100 g) for all the groups. Distilled water was measured with the help of a measuring cylinder with gradations of 0.5 mL and added into a rubber bowl.
1. For Group A and I (control group) 100 g dental stone was incorporated into 28 mL distilled water dispensed into the bowl. Initial mixing was done for 45 s followed by mechanical vacuum mixing for 30 s to get a homogeneous mix.

2. For Group B and II, 100 g dental stone was incorporated into 28 mL gauging water with NaOCl dispensed into the rubber bowl. Initial mixing was done for 45 s followed by mechanical vacuum mixing for 30 s to get a homogeneous mix.

3. For Group C and III, 100 g dental stone was incorporated into 28 mL gauging water with povidone–iodine dispensed into rubber bowl. Initial mixing was done for 45 s followed by mechanical vacuum mixing for 30 s to get a homogeneous mix.

Figure 6: Compressive strength of specimens was tested using Instron universal testing machine

The mix was carefully vibrated into the silicone mold. Glass slab was placed on top of the mold to obtain specimens with flat surface. They were allowed to set in the silicone mold for 40 min as per the manufacturer’s recommendation.

Using compressed air, the specimens were carefully retrieved from the mold [Figure 5]. For each group, 60 samples were made of these, 30 specimens were tested after 1 h and 30 specimens after 24 h. The specimens of dental stone were subjected to compressive loading 1 h from the mixing time and 24 h from the mixing time.

Compressive strength of specimens was tested using the Instron universal testing machine [Figure 6], at crosshead speed of 1 mm/min. Each specimen was placed between the metallic testing table of the Instron universal testing machine. A gradually increasing compressive load was applied till the specimen was crushed into fragments, and digitalized readings were recorded in Newton/(millimeter)$^2$ (MPa). The compressive strength for each specimen was obtained and recorded.

RESULTS

The results showed the mean compressive strength is higher in Group A (16.2133), followed by Group B (15.5370) and group C (12.6687) [Table 1]. No significant difference was observed in the mean compressive strength between Group A and B (P = 0.612), statistical significance was seen between Group A and C (P < 0.0005) and between Group B and C (P < 0.0005). The mean compressive strength was higher in Group I (20.6967), followed by Group II (19.4323) and Group III (18.1153) after 24 h. Statistical significance was observed between all the three groups [Table 2].

DISCUSSION

The disinfection of casts is important to prevent cross infection. In dentistry, personnel in dental technical and clinical laboratories handle materials that have been in either direct or indirect contact with patient’s

Table 1: The results Showed the mean compressive strength is higher in Group A (16.2133), followed by Group B (15.5370) and group C (12.6687)

|        | N  | Mean   | Std. Deviation | Minimum | Maximum |
|--------|----|--------|----------------|---------|---------|
| Group A| 30 | 16.2133| 3.53771        | 11.95   | 27.05   |
| Group B| 30 | 15.5370| 1.51719        | 12.28   | 18.53   |
| Group C| 30 | 12.6687| 2.85180        | 6.99    | 17.95   |
| Total  | 90 | 14.8063| 3.14097        | 6.99    | 27.05   |

F=13.888; p<0.0005
oral tissues. These materials include casts, dental prostheses, and appliances, which are often heavily contaminated with microorganisms from saliva and blood. Fabrication of these gypsum casts may cause cross contamination between patients and dental laboratory personnel. The oral environment harbors a large number of microorganisms in the saliva and blood that may contain infectious microbes. Although the majority of these organisms pose no significant risk to dental professionals, a number of them cause infectious diseases that may be incurable, such as those caused by the hepatitis C and HIV viruses. Recommendations exist for the use of safety measures and for the disinfection techniques required after impression making. Because of the difficulties associated with impression sterilization and disinfection, attention was directed toward cast sterilization or even disinfection. Previous research has shown that dental gypsum casts may be effectively disinfected by the substitution of water with disinfectant solutions. The purpose of this study was to evaluate the compressive strength of type III dental stone when disinfectant solutions were incorporated into the mixing water against a control group of type III dental stone mixed only with distilled water.

Physical properties of the materials involved in the fabrication of the prosthesis play a vital role, strength being the most significant property. It is the mechanical property of a material, which ensures that the material serves its intended purposes effectively, safely, and for a reasonable period. In a general sense, strength refers to the ability of the material to resist applied forces without fracture or excessive deformation. Gypsum and its products are brittle materials and their tensile strength is markedly lower than the corresponding compressive strength because of their inability to plastically deform under tensile stresses. As fracture of gypsum cast typically occurs in tension, tensile strength is a better guide to fracture resistance. The stress at which a material fractures is called the fracture strength. The strength of dental gypsum products has always been expressed as compressive or crushing strength, and almost all reported works on the subject have involved compressive strength measurements. This is an important property when plaster of Paris or dental stone is used as a mold material. But, in other cases, tensile strength is of more importance. The prevalence of these diseases and their potentially harmful effects mandates adherence to infection control procedures in the dental office and laboratory. It has been shown that gypsum casts made from contaminated impressions can be a medium for cross contamination between patients and dental personnel. There has been considerable concern over cross contamination of impressions, gypsum casts recovered from these impressions, and prostheses fabricated on these casts. There are recommendations to “rinse the recovered impression in a running water before pouring the impression” or “casts to be heated or gas sterilized” before working with them or sending them to laboratory personnel. Sterilization is a process by which all forms of microorganisms, including viruses, fungi, bacteria, and spores, are destroyed. Sterilization procedures such as “heat sterilization” can have damaging effects on dental cast, hence modern disinfection uses chemicals to destroy microorganisms. Synthesis of new and more effective chemicals and their newly established applications in disinfection has led to “cold sterilization.” Cold sterilization (disinfection) is a method in which an object is immersed in a liquid containing sanitizing chemical, which is used for objects that cannot withstand high temperature. Disinfection is a process in which disinfectants are applied to nonliving objects to destroy microorganisms. It has an antimicrobial effect. Disinfectants are a chemically diverse group of agents, which are generally considered to show poor selective toxicity. The interactions between bacterial cell and disinfectant agent are the physicochemical characteristics of chemical agent, which interfere with cell morphology and the physiological status of microorganisms. Antimicrobial events include membrane disruption, macromolecule dysfunction, and metabolic inhibition, which results in true microbial death. The ADA and the Centers of Disease Control and Prevention have suggested methods for the disinfection of dental casts, including immersion in or spraying with a disinfectant.

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| Group    | Mean        | Std. Deviation | Minimum | Maximum |
|----------|-------------|----------------|---------|---------|
| Group I  | 20.6967     | 3.64623        | 13.89   | 29.34   |
| Group II | 19.4323     | 5.96407        | 6.12    | 28.28   |
| Group III| 18.1153     | 2.92330        | 11.05   | 23.27   |
| Total    | 19.4148     | 4.45310        | 6.12    | 29.34   |

F=2.612; p<.079
It is important that these procedures and materials have no effects on dimensional accuracy.\cite{12} Disinfection is generally a less lethal process than sterilization. It eliminates all microorganisms, which are pathogenic but not necessarily all microbial forms (bacterial endospores) or inanimate objects. In immersion procedure of disinfection, dental casts are immersed into disinfectant incorporated distilled water. Craig et al. showed that dental stone casts showed increase in surface roughness after immersion in disinfectant solution.\cite{13,14} Rudd et al. showed that immersing a dental stone cast in tap water alone for 15 min altered surface properties. As it is recommended that a dental cast remains submerged in the solution for up to 30 min to achieve a disinfected surface, it is probable that there will be a negative effect on the surface integrity.\cite{15} In a study done by Mohammed Aleem Abdullah, he showed that repeating the process of immersing type III and type IV dental stone cylindrical specimens seven times in a slurry of NaOCl (0.525%) and subsequent drying reduced the compressive strength significantly more compared to the control specimens treated with clear slurry water.\cite{16}

The spray technique for disinfecting the surface of stone casts appears to eliminate the surface detail. The problem with spray disinfectants is the inability of the solution to completely cover and maintain contact with all the surfaces of the dental cast for the required amount of time, and undercut areas may be missed in the application of the solution.\cite{17} One solution to the problem of cast/impression cross contamination may be the incorporation of disinfectants into gypsum product at the time of mixing, thereby disinfecting the dental cast and the impression simultaneously. Terbrock et al. examined various sterilizing methods during several of dental cast production, finding that an addition of 5.25% NaOCl, as little as 25% by volume to the liquid produces a biologically safe dental cast. Robert et al. showed that when chloramine-T was activated with water, which was similar to a dilute form of NaOCl, which has bactericidal effect concluding that, it is a viable method for disinfecting dental impressions and dental stone casts.\cite{60} Hypochlorite of sodium and calcium are the oldest of the most widely used chlorine compounds in the field of chemical disinfection. The mechanism of action of chlorine is based on its powerful oxidizing effect and rapid linkage to proteins. Chlorine also attaches very easily to double bonds of biomolecules. These reactions have lethal effect on the metabolism of microorganisms. In addition, chlorine destroys the cell membrane and reacts with deoxyribonucleic acid of the microorganisms. NaOCl commonly known as bleach or liquid bleach and calcium hypochlorite is a chemical compound better known as bleaching powder, which is considered relatively stable and has greater available chlorine for disinfection. If disinfectants are to be incorporated into gypsum product, it should not affect the physical properties, meanwhile showing antimicrobial effect too, to serve the purpose. Breault et al. had conducted a study in which dental gypsum casts may be effectively disinfected by the substitution of 10% gauging water with 5.25% solution of NaOCl, and the results showed that there is an increase in the compressive strength and rigidity, decrease in the setting time and no change in the tensile strength, hardness, and setting expansion or detail reproduction. They concluded that the substitution may be an effective and convenient method of disinfesting gypsum casts in the laboratory without adversely affecting physical and mechanical properties.\cite{18} Povidone–iodine, one of the complexes of iodine with polyvinylpyrrolidone, is now widely used for surgical scrub and skin disinfection in hospitals. The bactericidal action of povidone–iodine is the result of free iodine released from the polyvinylpyrrolidone–povidone complex. This free iodine causes plasmolysis of the bacterial cells, thus killing the bacteria. In povidone–iodine solution, a small amount of free iodine is constantly released and remains in equilibrium with the complex until the available iodine is exhausted.\cite{19} According to International Specialty Products (ISP), the microbiocidal action of the povidone–iodine complex is related to the noncomplexed, freely mobile elemental iodine, I₂, the active form of which is polarized by water, and hence can be considered to be H₂O¹⁺ in its final state. The activated iodine reacts in the electrophilic reactions with enzymes of the respiratory chain and with the amino acids from the cell membrane proteins both located in the cell wall. As a result, the well-balanced tertiary structure necessary for maintaining the respiratory chain is destroyed, and the microorganism is irreversibly damaged. In this study, in agreement with the aforementioned studies, 3% NaOCl solution and 2% povidone–iodine solution were used. To prepare the gauging water, 10 mL of both solutions were added to 100 mL of distilled water in the ratio of 1:10 as per ADA standards. Then, type III dental stone was measured in the electronic weighing machine and incorporated into gauging water separately. The mix was incorporated into silicone mold, which was fabricated from metal die of dimensions 40 mm height and 20 mm diameter, according to ADA specification number 25, duplicated using the silicon-duplicating material. In this study, a popular brand of dental stone
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was used, which was easily available in the market. The specimens in each type were divided into three groups and tested for compressive strength using an Instron universal testing machine at a crosshead speed of 0.5 mm/min. Values obtained were statistically analyzed using one-way analysis of variance (ANOVA). The first three groups were tested at 1 h from the time of mixing and the second three groups were tested after 24 h from the time of mixing. It was concluded that the compressive strength of the specimens after 1 h had very low compressive strength with the control group having the maximum compressive strength of 16.20 MPa, and the incorporation of NaOCl and povidone–iodine significantly decreased the compressive strength, both having a compressive strength of 15.53 MPa for samples mixed with NaOCl and 12.69 MPa for samples mixed with povidone–iodine. After 24 h, the compressive strength was increased with the control group having a compressive strength of 20.69 MPa. The samples in which NaOCl was incorporated had a compressive strength of 19.43 MPa, and the samples in which povidone–iodine was incorporated had a compressive strength of 18.11 MPa. Thus, after 1 h and 24 h, the compressive strength of the control group was maximum, and the compressive strength of the samples in which povidone–iodine was incorporated was the least after both time intervals. An overall statistical analysis using one-way ANOVA and Tukey honestly significant difference multiple comparisons, which signifies that after 1 h, a significant difference was observed between the control Group A (only distilled water) and control Group B (NaOCl-incorporated samples). The statistical difference between Groups A and C (povidone–iodine incorporated samples) was statistically significant, and the comparison between Groups B and C was statistically significant. After 24 h, a significant difference was observed between the control Group A (only distilled water) and control Group B (NaOCl-incorporated samples), and the statistical difference between Groups A and C (povidone–iodine incorporated samples) was statistically significant, and the comparison between Group B and C was statistically significant. In this study, the compressive strength of type III dental stone in which NaOCl was incorporated after 1 h and 24 h was less than that of the control; the reason for this can be explained by a study done by Breault et al. The assumption is that in the normal setting reaction, the amount of water that reacts with calcium sulfate hemihydrates is determined stoichiometrically. The excess water is distributed as free water and contributes to volume but not strength. Therefore, strength increases as the W/P ratio decreases. Whereas NaOCl solution contributes to fluid, workable mix, which does not take part in the reaction, with calcium sulfate dihydrate leaving some excess unreacted water during initial setting. Simultaneously, the disinfectant later may have reacted with the gypsum to produce the increased roughness and an increase in porosity, which weakens the specimens, leading to less fracture strength. In agreement with the studies done by Abdelaziz Khalid et al., Jonathan et al., and Breault et al., the assumption is that the sodium ions from the hypochlorite interfere with the structure and strength

Graph 1: In agreement with the aforementioned study, the compressive strength of the type III gypsum mixed with povidone–iodine, which was mixed in this study, showed lower values after 1 h and 24 h when compared to both the control group mixed with water and also the group in which sodium hypochlorite was incorporated
of gypsum, which contain calcium in its structure. In a study by Abdelaziz Khalid et al., they said the hemihydrate particles may be incompletely soluble in the povidone–iodine, affecting the final percentage of hemihydrate/dihydrate conversion. Also, the excess povidone–iodine takes time to evaporate and therefore there is moisture left in the samples, which reduces the strength of the specimen.[20]

In agreement with the aforementioned study, the compressive strength of the type III gypsum mixed with povidone–iodine, which were mixed in this study, showed lower values after 1 and 24 h when compared to both the control group mixed with water and also the group in which NaOCl was incorporated [Graph 1].

Limitation of the study
In this study, samples were prepared in accordance with ADA specification number 25, and the study was designed and carried out with utmost accuracy. This study had a limitation: the specimens fabricated as per the ADA specification, which were used for the three study samples, failed to deliver adequate results but were included in the statistical analysis as they did not affect the statistical analysis.

Scope for further studies
This study was focused only on type III gypsum and two disinfectant solutions NaOCl and povidone–iodine, and only the compressive strength was tested; the scope for further studies could be to check the effect of these disinfectant solutions on the surface hardness and tensile strength of these specimens.

Conclusion
Within the limitations of this study and on the basis of results obtained, it can be concluded that:

1. The incorporation of NaOCl and povidone–iodine disinfecting solutions is not an encouraging method for disinfecting type III gypsum as it reduces the compressive strength of type III gypsum product.
2. The compressive strength of the control group in which type III gypsum was mixed with water has a higher compressive strength than both the groups that were mixed with disinfecting solution.
3. The effect of decreasing compressive strength on type III gypsum product is seen more in povidone–iodine when compared to NaOCl disinfecting solution.

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Conflicts of interest
There are no conflicts of interest.

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