

Effect of Disinfectants on the Hardness of Dental Stones

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Abstract

Background and Aim: Considering the risk of cross contamination, disinfection of dental stones is essential provided that their mechanical and structural properties remain unchanged. The aim of this study was to evaluate the effect of disinfection on the hardness of dental stones.

Materials and Methods: In this experimental study, 40 discs were fabricated of type III and IV dental stones and divided into three groups. The three understudy chemical disinfectants namely 1% Virkon, 0.525% hypochlorite and slurry water were sprayed on samples in each group. The hardness of sprayed samples was evaluated by measuring the width of scratch according to the Mohs scale of mineral hardness. Surfaces of sprayed samples were also inspected by optical microscopy. Data were analyzed using Kruskal-Wallis and Mann-Whitney tests ($P < 0.05$).

Results: Mohs scale of mineral hardness revealed that the width of scratches was narrower in samples sprayed with Virkon than in those sprayed with hypochlorite and slurry water. In type III dental stone specimens, the maximum width was observed in samples sprayed with slurry water (1.35 ± 0.02) and the minimum width was observed in Virkon group samples (0.97 ± 0.01). For type IV, the maximum and minimum widths were observed in samples sprayed with slurry water (1.20 ± 0.01) and Virkon (0.61 ± 0.01), respectively. In both types of stones, no significant differences were noted between the sprayed groups, while the differences between each sprayed group and the control stones (no spraying) were significant.

Conclusion: Surface hardness of dental stones decreased after spraying them with the three understudy disinfectants. Dental stones sprayed with Virkon exhibited the lowest reduction in hardness.

Key Words: Gypsum, Hardness, Sodium hypochlorite, Virkon

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Introduction

There are several applications for gypsum in dentistry such as fabrication of study casts for fixed, partial and complete dental prostheses. Direct and indirect contact between the dental casts and patients' saliva may lead to cross contamination in dental laboratory setting. Therefore, disinfection of dental casts is required to avoid transmission of infectious agents.

Immersion of dental casts in chemical solutions as a general disinfection method suffers several dis-

advantages including dissolution of gypsum and change in its initial dimensions. Therefore, this technique has been replaced by the application of disinfectant sprays to overcome the deficiencies of the immersion technique such as the high volume of disinfectants used and also the need for their exchange. Different types of disinfecting solutions are used in dentistry including glutaraldehyde, phenol, Idophor, chlorine and sodium hypochlorite; among which, sodium hypochlorite is the most commonly used agent due to its

low cost, availability and its potent antimicrobial property against hepatitis, HIV, SARS and gram-positive and gram-negative bacteria. However, this disinfectant has low chemical stability and needs to be replaced daily. In addition to their antimicrobial property, disinfecting agents should not compromise physical or chemical properties of dental stones [1, 2]. Tebrok et al. reported that application of 0.525% sodium hypochlorite solution was microbiologically effective within 30 min of application [3]. Sarma and Neiman assessed the effect of 0.525% sodium hypochlorite on the mechanical properties of die stones and reported the least changes in their physical properties [4]. Fabrication of dental prosthesis requires several patient visits and is associated with a high risk of cross contamination. According to a study by Stern *et al.* seven cycles of disinfection are required for the fabrication of complete or removable partial dentures [5].

Hypochlorite has no toxicity for the eyes or skin of personnel or corrosive effect on dental instruments. Virkon is a disinfecting agent produced in Iran under the license of the manufacturer and has been extensively used over the past 40 years. It has bactericidal properties with no irritating effect on the eyes or skin. It does not release toxic chlorine vapors either. Gasparini et al. studied the effect of Virkon on different microorganisms and demonstrated its significant effectiveness against a wide spectrum of bacteria, hepatitis virus and bacterial spores [6]. This chemical agent has a color indicator and its discoloration indicates the ineffectiveness of solution and the need for its replacement. Limited number of studies have evaluated the application of Virkon in dentistry. It has no adverse effect on impression materials or burs and no microbial growth has been observed after disinfection [6-7].

In another study, it was demonstrated that the compressive strength of type III and IV stone casts disinfected with hypochlorite solution reduced by 5.7%. In another study, disinfectants were incorporated into the model stones (instead of water) made of type III and IV dental stones and it was noted that their tensile and compressive strengths decreased in comparison to control samples. Furthermore, this mixture preserved its antimicrobial

property for only an hour and needed to be disinfected again after transfer to the lab [8, 9].

Hypochlorite is a popular disinfecting solution with high toxicity. Virkon is a safe substance with adequate disinfecting properties. Thus, considering the fact that in the process of denture fabrication, casts and articulator need to be transferred from the office to the lab and vice versa for at least 7 times, a safe effective disinfection technique is critical [8].

This study aimed to investigate the effect of chemical disinfection (by spraying samples with three types of disinfectants namely 0.525% sodium hypochlorite, 1% Virkon and slurry water) on the hardness and structure of type III and IV dental stones.

Materials and Methods

Samples made of type III and IV dental stones were disinfected by spraying them with slurry water with and without disinfectants. The disinfectants were 0.525% sodium hypochlorite (Pakshoo Chemical & Manufacturing Co., Iran) and 1% Virkon (Antec International, Sudbury, Suffolk, UK) solutions. The Virkon spray was prepared according to the manufacturer's instructions and one tablet of Virkon was added per 500 ml of warm water and mixed until fully dissolved.

2-1- Preparation of gypsum specimens

Specimens were fabricated of type III (Elite Model, Zhermack, Italy) and type IV improved dental stones (Elite Model, Zhermack, Italy). Hardness test samples were prepared according to ADA specification No.25 measuring 40 mm in diameter and 10 mm in height and attached to a metal substrate. Impressions were made using a silicone impression material. A hardness test sample fabricated specifically for this study is demonstrated in Figure 1.



Figure 1: Hardness test sample

The recommended amount of powder was added to the slurry water in a rubber bowl and mixed by hand until a smooth consistency was achieved. To reduce porosity, the dental stone was placed in a vacuum mixer (BEGO-Motova SC, Bremen, Germany) at 1750 rpm under 28 lb for 20 seconds to draw out air bubbles from the slurry. The mixed dental stone was poured into the silicone mold on a mechanical vibrator (Vibromaster, BEGO, Bremen, Germany), and a glass slab was placed over the mold to ensure flat and parallel ends. The specimens (40 in number, 10 in each group) were allowed to set for one hour at ambient room temperature of $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and $50\% \pm 10\%$ relative humidity. After a setting period, the cylindrical specimens were removed from the molds. Finally, all specimens were coded. In order to prepare slurry water, pieces of gypsum were immersed in distilled water for 48 h and this water was then used to make other disinfectant solutions with respective concentrations. Test groups were divided into four subgroups of type III and IV dental stones as prepared before disinfection, and after disinfection with 1% Virkon, 0.525% hypochlorite and slurry water. There were 10 samples in each group.

2-2- Disinfecting solution preparation

The effect of three different solutions was examined on the compressive and tensile strengths of two types of gypsum specimens. The tested solutions were (1) 0.525% sodium hypochlorite in slurry, (2) 1% Virkon in slurry, and (3) slurry water as the control. Slurry water was prepared by placement of clean, completely set dental stones in a plastic container filled with distilled water and allowing them to soak for 48 hours. The solutions except for slurry were changed every day. In order to obtain the desired concentration of sodium hypochlorite (0.525%) the commercial product was diluted by 10 times and prepared daily to ensure its efficacy. For preparation of 1% Virkon, according to the manufacturer's instructions, one Virkon tablet was dissolved in 500 cc slurry water daily. Specimens were sprayed until the spray no longer penetrated into the dental stone and its residues accumulated on the stone surface. The process of spraying and drying was repeated 7 times (due to the need for 7 times disinfection required in the process of denture fabrication) at seven days with 24- hour intervals. The specimens were allowed to

air dry for 24 hours between cycles and before testing. The compressive strength, tensile strength and hardness of two types of stones after 7 cycles of disinfectant spray were examined and evaluated according to the ADA specification No.25.

2-3- Hardness test

Hardness of dental stones was measured according to the Mohs scale of mineral hardness [10]. The Mohs scale is a comparative, purely ordinal scale based on the hardness of 10 different standard minerals with a range of 1 to 10; the smaller the number, the lower the hardness. Minerals in Mohs scale are summarized in Table 1.

Table 1: Mohs hardness scale and the corresponding Vickers' hardness values

Substance	Mohs hardness scale	Vickers hardness value
Talc	1	27
Gypsum	2	61
Calcite	3	157
Fluorite	4	315
Apatite	5	535
Feldspar	6	817
Quartz	7	1161
Topaz	8	1567
Corundum	9	2035
Diamond	10	-

This scale is based on the ability of one substance to scratch another mineral. A material's hardness is measured against the scale by finding the hardest material that the given substance can scratch, and/or the softest material that can scratch the given material. For example, if a given substance is scratched by mineral #6 but not by mineral #5, its hardness on the Mohs scale would fall between 5 and 6. The obtained scale can be converted to Vickers hardness scale. The 10 minerals (numbered 1 to 10) mentioned in Table 1 were tested on the samples using standard instruments. We used Talc with a Mohs score of one as the scratcher. For comparison of the hardness of samples and considering the converse correlation between the substance hardness and the width of scratch, scratch width was selected as a quantitative index. Scratch widths were measured under optical microscope (Olympus-65X stereomicroscope) with 0.01 mm readability.

Kruskal Wallis and Mann Whitney U tests along with SPSS version 13.0 software were applied for statistical analysis. $P < 0.05$ was considered statistically significant.

Results

The maximum, minimum, mean values and standard deviations of scratch width in two dental stone samples are summarized in Table 2. Samples in this study were scratched by Talc (#1). Therefore, their hardness was even lower than the lowest hardness in Mohr's scale. Based on references, the hardness of disinfected dental stones is estimated as less than 27 Vickers; whereas, the hardness of control samples according to Mohs scale was 2 or equal to 61 Vickers. Our test samples were scratched by Talc with a Mohs scale of 1; thus, they had a hardness scale less than one. Kruskal Wallis test was used for overall comparison and Mann Whitney U test was applied for pair-wise comparison of results. The results were the same for type III and IV dental stones. Kruskal Wallis

test revealed differences between groups. Mann Whitney U test did not find significant differences between disinfected groups. But, significant differences were noted between test and control groups. However, the width of scratch in Virkon samples was smaller than that in other groups in both type III and IV dental stones. Figure 2 shows the macroscopic images of samples tested for hardness that were scratched by talc.

Most samples were fractured in half and the fracture surfaces were inspected before and after disinfection under a light microscope. Microscopic images of the fracture surfaces of type III and IV dental stones are illustrated in Figures 3 and 4. As observed, there are several pores on the fractured surfaces marked by arrows. The number of pores was higher in samples disinfected by sodium hypochlorite and slurry water compared to Virkon. Size of pores was also larger in samples in the first two groups; which indicates higher strength of Virkon samples in comparison to samples disinfected with hypochlorite and slurry water.

Table 2: Statistical data for the scratch width

Maximum (mm)	Minimum (mm)	Mean \pm standard deviation (mm)	Disinfectant (dental stone)
0.98	0.96	0.97 ± 0.01	Virkon (Type III)
1.17	1.15	1.16 ± 0.01	NaOCl (Type III)
1.35	1.30	1.35 ± 0.02	Slurry water (Type III)
0.63	0.59	0.61 ± 0.01	Virkon (Type IV)
1.05	1.02	1.03 ± 0.01	NaOCl (Type IV)
1.21	1.18	1.20 ± 0.01	Slurry water (Type IV)
0.53	0.45	0.49 ± 0.01	No spray (Type III)
0.30	0.22	0.26 ± 0.01	No spray (Type IV)

Discussion

Failing to follow basic principles of infection control by technicians and dentists during fabrication, trying and delivery of dental prosthesis is a serious threat to the health of healthcare personnel. Infectious agents can easily transmit through blood and saliva to the casts, wax occlusal rims, dentures and articulators. Therefore, they have to be disinfected after each clinical or laboratory phase. There is also a risk of cross-contamination between patients

and dental personnel working on dental casts. There are several infection control and disinfection protocols currently used in prosthodontic offices. A particular attention is devoted to the disinfection of impressions and casts utilized in the fabrication of the prostheses [11]. Immersion of casts in the disinfecting solution, or spraying them with disinfecting agents, incorporation of specific chemical products into the dental stones during mixing and use of die stones containing disinfecting agents are

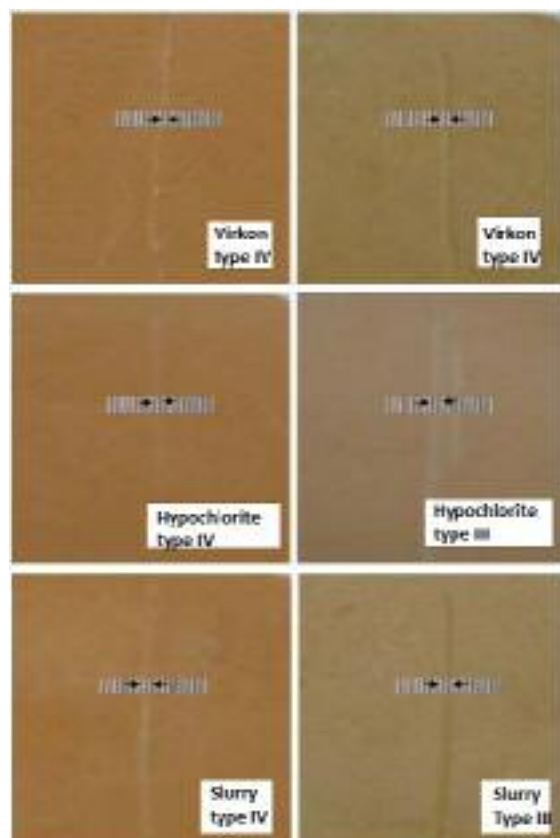


Figure 2: Width of scratch according to Mohs scale of mineral hardness in different dental stones disinfected with various solutions.

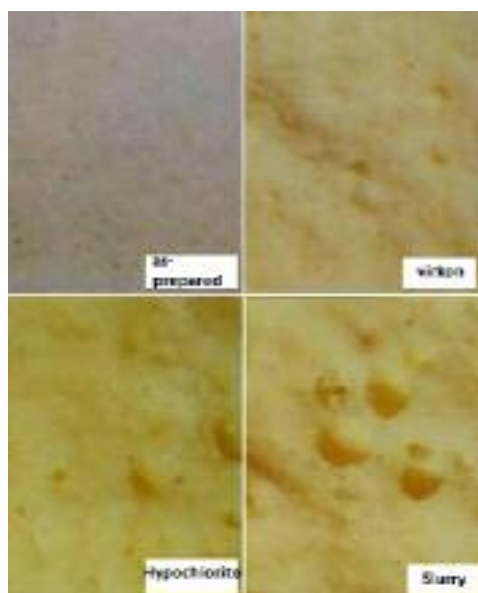


Figure 3: Optical micrographs obtained at 25×1.25 magnification from the fracture surface of type III dental stones before and after disinfection with different solutions

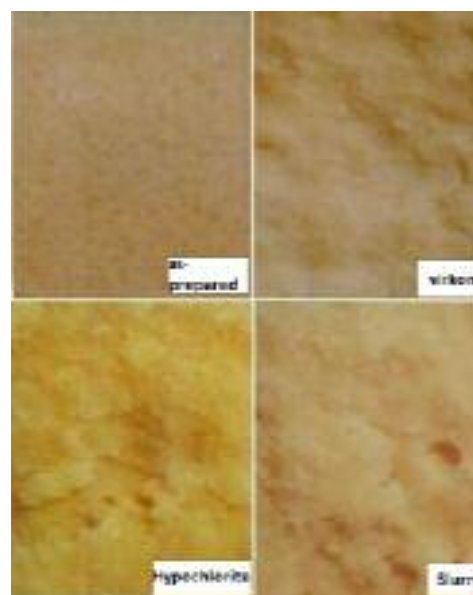


Figure 4: Optical micrographs obtained at 25×1.25 magnification from the fracture surface of type IV dental stones before and after disinfection with different solutions

among the disinfection techniques suggested for this purpose [1]. Dental casts should have a high mechanical strength and be resistant to fracture and abrasion in order to be clinically useful [12].

Therefore, evaluation of the mechanical properties of dental casts after the disinfection process is a matter of significance. The majority of studies on this issue have focused on the measurement of tensile and compressive strengths of casts. Abdullah in his study compared the compressive strengths of dental stones disinfected with hypochlorite with that of controls and reported that stone casts fabricated by type III dental stone showed a reduction in the compressive strength by 5.7% after disinfection with hypochlorite for one hour [8]. Ivanovski et al. compared tensile and compressive strength of type III and IV dental casts fabricated with incorporation of chemical disinfectants instead of water and observed a reduction in their mechanical properties. Also, this mixture retained its antimicrobial activity for only an hour and after delivery to the lab needed to be disinfected again [9].

Little information exists on the effect of chemical disinfection on the hardness of dental stones. Available studies in this regard have all reported a reduction in hardness of casts after wetting; which is in agreement with the current study results.

Mahler used Rockwell hardness measurement with a large penetrator under small loading and reported that the hardness decreased after disinfection [13]. They also investigated the effect of amount of water added during the process of setting on the surface hardness of dental stones and calculated the specific water percentage that has to be added. This issue will be discussed later in this article. Abdelaziz et al. [2] studied the effect of disinfection on the surface hardness of casts using Knoop micro-hardness test. They demonstrated insignificant reduction in hardness of casts in the test group subjected to disinfection with hypochlorite and etc. compared to controls (or baseline samples). In order to compensate this reduction in hardness, they suggested the use of additives such as Arabic gum or calcium hydroxide. In another study, Fusayama [14] mentioned the reduction in hardness of wet gypsum. He immersed gypsum samples in water for 5 min and concluded that penetration of water into the gypsum structure led to a reduction in hardness [14]. Fair Hurst [15] stated that the reduction of hardness is attributed to an irreversible plastic deformation due to water. Johansson et al. studied the effect of water and water-soluble lubricants on gypsum and noted that wetting of gypsum decreased its hardness [16]. Furthermore, Peyton et al. demonstrated that wetting of dental stones reduced their surface hardness [17].

In order to analyze the reduction in hardness, we investigated the mechanical properties of stones and their setting process in this respect [18]. In general, the mechanical behavior of dental stones follows the general behavior of most ceramics. They mostly undergo an elastic deformation followed by an abrupt brittle failure (rupture). This phenomenon was also observed in our understudy samples. Light microscopy analysis demonstrated that the percentage of porosity varies based on the type of used disinfecting agent. The amount of reduction in hardness differs for each spray. Both types of dental stones at room temperature are elastic to a good approximation. However, according to our findings published elsewhere [18], a non-linear behavior exists in stress-strain curve of dental stones due to the presence of porosity in their structure. The greater the porosities, the more significant the reduction in the elastic modulus and the hardness. Optical micrographs shown here ex-

hibit the presence of micro-pores inside the structure. The formation of pores is due to the reaction taken place after moisturizing the gypsum. The exothermic reaction of dental stone setting can be represented as follows:

$$\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O} + 3/2\text{H}_2\text{O} \rightleftharpoons \text{CaSO}_4 \cdot 2\text{H}_2\text{O} + \text{Heat}$$
 (3900 cal/g.mole) Setting of gypsum is attributed to the variable solubilities of di- and hemihydrates. A dissolution centre surrounds the hemihydrate during the process of rehydration. A precipitation center also develops around the dehydrate. Therefore, it is believed that the structural changes take place in the intercrystalline boundaries or separations, which are the shortest distances between the crystals and consequently the last locations to lose water when drying and the first locations to absorb water during the disinfection of gypsum. During the continuous precipitation of gypsum, the majority of gypsum-water solution is located only in smaller crystal boundaries. Since the space available for precipitation of crystals is small, an intercrystalline union forms and continues to build microcrystallites until all water is evaporated. We observe that the hemihydrate phase still remains after setting of the gypsum before disinfection and can still react with water during disinfection. This leads to the formation of pores. The reduction of hardness can be attributed to the formation of pores; however, the intensity of this reduction differs for different disinfectants. Hardness of type III and IV dental stone samples disinfected by Virkon was the highest among the three groups.

Conclusion

In this study, the Mohs scale of mineral hardness was used to evaluate the hardness of type III and IV dental stones after chemical disinfection. This qualitative method benefits dentists and lab technicians and assists them to easily assess the mechanical properties of casts by hardness measurements. The formation of micropores was found to be responsible for the reduction of hardness; which was minimal in dental stones disinfected with Virkon. As a generally accepted rule, gypsum is dissoluble in water. But one needs to consider the effect of different disinfectants on the degree of gypsum hardness reduction.

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