Original Article

Effects Chemical Disinfectants on Surface Roughness of Conventional Impression Materials used for Dental Prosthetic Procedures

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Abstract

Background to Aim: To compare the effects of disinfectants on surface roughness of the conventional impression materials following chemical disinfection procedures. **Materials and Methods:** Equal numbers (65 for each impression material) of disc-shaped (15 × 3 mm) samples (Total n = 195) were fabricated from polyvinyl siloxane (Zhermack Elite), polyether (3M Impregum Penta Soft), and vinyl siloxane ether (Kettenbach Identium Lightbody) impression materials. Each impression material group was divided into five subgroups including one control group (n = 13). Impression material samples were immersed in CaviCide for 3 min, Zeta 7 solution for 10 min, and 5.25% sodium hypochlorite solution for 3 and 10 min. Surface roughness (Ra) was measured using a profilometer (Mitutoyo-SJ 410, Mitutoyo Corp.). The study data were analyzed statistically. **Results:** A statistically significant difference was found among impression materials and disinfectants in terms of surface roughness ($P < 0.05$). Polyvinyl siloxane material showed a lower Ra value compared to Polyether and VSE materials; while polyether material showed a significantly lower Ra value compared to VSE material. Ra values of the control group were significantly lower than the disinfectant group immersed in 5.25% NaOCl solution for 10 min. **Conclusion:** Among all impression materials, polyvinyl siloxane showed the least surface roughness following disinfection procedures. Impression disinfectants that are specially designed for disinfecting dental impressions resulted in less surface roughness in all impression materials. With this study, it was aimed to obtain a smooth and clear model for the production of correct and compatible prostheses in the laboratory while at the same time purifying the impressions from microorganisms.

Keywords: *Conventional, disinfection, impression materials, surface roughness*

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Introduction

Despite the current popularity of digital dentistry concept, conventional impression materials including implant-supported prostheses are still used in many patients. Public awareness of the potential for the transmission of microorganisms and infectious diseases among dentists, dental technicians and laboratory staff working at dental clinics has increased considerably after the COVID-19 pandemics.[1] Some microorganisms are normally nonpathogenic but may cause opportunistic infections in immunocompromised individuals including those with hepatitis, tuberculosis, herpes, and AIDS.[2] Studies have shown that gypsum casts poured from infected impressions can also be contaminated. Various methods are available for disinfecting impression materials. The easiest and most commonly used method is rinsing with water. It is recommended that all dental materials be disinfected using an active hospital disinfectant and rinsed before

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they are handled in the laboratory.[3] In order to prevent cross-infection, disinfection of impressions is now regarded as a routine practice and most often disinfectant solutions are used for this purpose. A wide range of disinfectant solutions are commercially available; however, recommendations on which disinfectant to use vary depending on the properties of the disinfectant and the nature of the impression used.[4] Glutaraldehydes, chlorine compounds, phenols. and iodophors are suitable chemicals routinely used for disinfection of prosthetic impression materials. All of these chemicals have been proven to be effective against viruses, bacteria and spores.[5] Unfavorable results associated with the use of disinfectant substances include changes in surface chemistry and altered dimensional stability.[6,7] Two different methods are used for chemical disinfection of impressions including spray disinfection and immersion disinfection. Immersion method has been reported to be safer and more effective.[8]

An impression with surface defects or irregularities may result in an inaccurate dental prosthesis. A smooth surface is desirable to ensure hygiene and improve aesthetics. Any surface irregularities in the prosthesis may affect the fit of the prosthesis. Such irregularities may result from changes in the material characteristics following disinfection procedures.[5]

The American Dental Association (ADA) and the US Centers for Disease Control (CDC) recommend disinfection of splashes of blood or fluids from human body or all surfaces touched by humans using a hospital grade disinfectant certified by the Environmental Protection Agency. Therefore, impressions should be disinfected within a short time using a disinfectant solution to avoid impairment of surface properties of the impression.[9]

Polyvinyl siloxane (PVS) impression material has a high dimensional accuracy and stability. Owing to its excellent elastic recovery, it allows multiple pours of casts. Polyether impression materials also possess this feature.[6]

Polyether impression materials do not form any byproducts upon polymerization reaction and can be poured within one week due to its high dimensional stability. These materials reproduce excellent surface details and have a high resistance to tearing.[7]

Vinyl siloxane ether (VSE) impression material which is a combination of polyvinyl and polyether impression materials offers the state-of-the-art features of the two materials in a single material. A hydrophilic material is thus obtained without using the surfactants found in the polyether group. With the siloxane group, the material has greater dimensional stability and shows elastic recovery after deformation.[8,10]

In dental practice, contact profilometer equipped with a diamond stylus is most commonly used for the measurement of surface roughness.[11] The diamond stylus with a diameter of 1.5–2.5 microns makes measurements by applying a force in the magnitude of 0.05–100 mg on the surface to be examined.[12,13]

The aim of this laboratory study was to compare surface roughness of the most ideal conventional impression materials following disinfection procedures using different disinfectants by immersion method. The first null hypothesis of the study was that the use of different disinfectant solutions would not affect surface roughness of the impression material. The second null hypothesis was that disinfectant solutions would not have differential effects on surface roughness of the impression materials.

Materials And Methods

This *in vitro* study was approved by the Local Non-Interventional Clinical Research Ethics Board of Firat University (2021/07 -06). A power analysis was done for the sample size to be examined in the study at a significance level of 0.05 and using the PASS 2015 (NCSS, Kaysville, Utah, USA) software, it was determined that optimally 13 samples of the dental impression materials would be needed for each sub group. Three different elastomeric impression materials were used for the study [Table 1].

A total of 195 disc-shaped , 13 × 5 samples (65 samples for each material) were fabricated using a metal ring made of stainless steel as per ADA specification 19[14] to ensure dimensional stability [Figure 1]. During the impression taking step, the impression material was placed in the mold cavity such that the exposed parts of the metal ring surface came into contact with the glossy glass surface and left to polymerize for a period of time (polymerization time for PVS 2:30 min, for VSE 2:15 min, and for polyether 6 min) recommended by the manufacturer.

Each impression material group (PVS, Polyether and VSE) was divided into the following subgroups: Non-disinfected (control group), Disinfection in 5.25% Sodium Hypochlorite solution for 3 min, Disinfection in 5.25% Sodium Hypochlorite solution for 10 min, Disinfection in Zeta 7 Solution (Zhermack SpA, Italy) for 10 min and, Disinfection in CaviCide (Metrex Research LLC, Orange, CA, USA) for 3 min. The waiting time stipulated by the manufacturer's

for each disinfectant was strictly followed during disinfection procedure. Disinfection was carried out at room temperature (68–72 F).

At the end of specified waiting times, the samples were rinsed under running tap water for 10 seconds to remove any residual disinfectant and dried.

Surface roughness of the samples was measured using a Mitutoyo Portable Surface Roughness tester SJ-410 (Mitutoyo Corp, Japan) at a stylus speed of 0.5 mm/s and a tracing length of 2.5 mm/s. Prior to measurements, the device was calibrated. For each sample surface, measurements were obtained from three different points and the average of 3 surface roughness (Ra) values was included in the study [Figure 2].

The SPSS 21.0 (IBM, Chicago, IL, USA) software package was used for the statistical analysis of the study data. The normality of data distribution was checked using Shapiro–Wilk and/or Kolmogorov–Smirnov tests as these tests were considered appropriate due to the sample size. For the interpretation of the results, the significance level was set at 0.05 and a normal distribution of the variables was considered in the case of a $P < 0.05$ and a non-normal distribution was considered when the P was >0.05. Differences among groups in variables with a non-normal distribution were analyzed using the Kruskal–Wallis H test. When significant differences were observed, post-hoc tests were employed to determine the groups showing significant differences.

Results

In all the disinfectant groups, VSE had the greatest surface roughness followed by polyether and PVS had the least surface roughness.

A significant difference was found among the disinfectant groups in Ra values ($P < 0.05$). Control group had a significantly lower Ra value in comparison to the NaOCl 10 min disinfection group [Figure 3].

There was a significant difference in Ra values of polyether impression material after exposure to different disinfectants ($P < 0.05$). For the polyether impression material, the Ra values of the control were significantly lower compared to those of CaviCide 3 min, NaOCl 3 min and NaOCl 10 min disinfectant groups and the Ra values of Zeta 10 min disinfectant group were significantly lower compared to those of NaOCl 3 min and NaOCl 10 min disinfectant groups.

For the PVS impression material, a significant difference was observed in Ra values among the disinfectant groups ($P < 0.05$). Among the PVS impression material groups, control group showed a significantly lower Ra value than NaOCl 10 min disinfectant group.

A significant difference was found among the disinfectant groups of the VSE impression material in

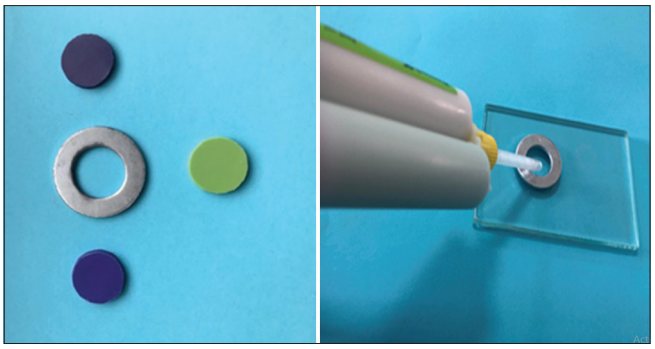

Figure 1: The metal ring used and impression materials produced are shown

Figure 2: Surface Roughness Measurement Device (Mitutoyo Corp., Japan) and Sample Surface Tested at Three Different Points

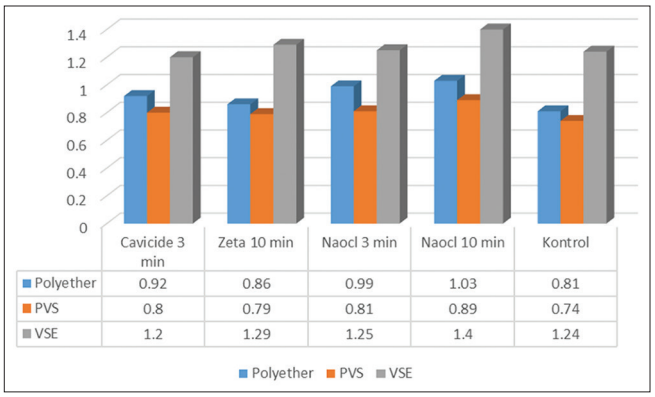

Figure 3: Differences in Ra values of impression materials following immersion in different disinfectants

Table 1: Impressions used for the study

Polyether	PE, Impregum Penta Soft; 3M ESPE, USA
Vinyl siloxane ether (VSE)	Identium Light, Kettenbach, Eschenburg, Germany
Polyvinyl siloxane (PVS)	Elite HD+light body, Zhermack, Italy

Table 2: Differences in Ra values within and among impression material groups by the disinfectant used

	Measurement Values (Ra)						Analysis Result		
	n	Mean	Median	Min	Max	SD	Mean Rank	H	*P*
Polyether									
CaviCide 3 min	13	0.92	0.93	0.76	1.00	0.07	33.85	39.136	0.001
Zeta 10 min	13	0.86	0.85	0.79	1.00	0.06	21.15		
NaOCl 3 min	13	0.99	1.00	0.86	1.09	0.07	45.46		
NaOCl 10 min	13	1.03	1.05	0.88	1.13	0.08	52.00		
Control	13	0.81	0.81	0.73	0.88	0.05	12.54		
Total	65	0.92	0.92	0.73	1.13	0.1		5-1 5-3 5-4 2-3 2-4	
PVS									
CaviCide 3 min	13	0.8	0.78	0.74	0.92	0.05	32.27	18.525	0.001
Zeta 10 min	13	0.79	0.81	0.73	0.84	0.04	30.92		
NaOCl 3 min	13	0.81	0.81	0.72	0.94	0.07	35.12		
NaOCl 10 min	13	0.89	0.89	0.77	1.08	0.09	49.15		
Control	13	0.74	0.77	0.6	0.81	0.07	17.54		
Total	65	0.81	0.79	0.6	1.08	0.08		5-4	
VSE									
CaviCide 3 min	13	1.2	1.21	1	1.34	0.1	22.23	12.87	0.012
Zeta 10 min	13	1.29	1.28	1.12	1.44	0.09	35.54		
NaOCl 3 min	13	1.25	1.26	1.1	1.4	0.09	29.50		
NaOCl 10 min	13	1.4	1.45	1.08	1.6	0.17	47.54		
Control	13	1.24	1.25	0.96	1.41	0.15	30.19		
Total	65	1.28	1.27	0.96	1.6	0.14		1-4	

Ra values ($P < 0.05$). For the VSE impression material, CaviCide 3 min disinfectant group had a significantly lower Ra value when compared with NaOCl 10 min disinfectant group [Table 2].

Discussion

In this *in vitro* study, surface roughness of disinfected and non-disinfected polyether, VSE, PVS elastomeric impression materials and the effects of two different surface disinfectants and sodium hypochlorite in aqueous solution on surface roughness were compared. The results showed significant differences and therefore, our hypotheses were rejected.

Despite the widespread use of intraoral scanners in dental practice, elastomeric impression materials are still commonly used due to their excellent ability to reproduce surface details, good physical characteristics and high clinical performance.[15–17] The current study obtained data on the effects of different materials of immersion in sodium hypochlorite disinfectant and EPA-certified quaternary ammonium-based surface disinfectant on surface roughness.

Polyvinyl siloxane (PVS) impression materials were introduced in 1970s. Compared to other impression materials, PVS materials meet most of the ideal impression material criteria as they display low polymerization shrinkage, high dimensional stability and good surface details without formation of any byproducts.[15,16] In our study, PVS material showed the least surface roughness when surface roughness was compared among ideal impression materials after disinfection using the immersion method.

Hypochlorites are the most commonly available and oldest chlorine compounds used as chemical disinfectant for impression materials. Hypochlorites are inexpensive, fast acting and easy to use. Disinfection of blood spills and splashes with a 1:10 dilution of 5.25% sodium hypochlorite is recommended by the CDC.[2] It was observed in our study that surface roughness increased with longer duration of exposure when the samples were compared after immersion in 5.25% sodium hypochlorite for 3 min and 10 min. Estafanous *et al*.[18] reported that spray or immersion disinfection for 10 min stopped the growth of bacteria on impression materials tested.

In one study, Karaman *et al*.[19] compared surface roughness of the PVS impression material by applying NaOCl and quaternary ammonium-based surface disinfectants for different time periods. They observed that while surface roughness increased significantly with prolonged application time of Sodium Hypochlorite disinfectant, application time of the quaternary ammonium-based disinfectant was not associated with a significant change in surface roughness. Similarly, surface roughness increased with prolonged application of NaOCl, and quaternary ammonium-based disinfectants caused less surface roughness in our study.

Farooqui *et al*.[1] compared the surface roughness of two different PVS impression materials following UV irradiation and chemical disinfection by dividing the samples into three groups (one control and two experimental groups). One group was disinfected with immersion in 2% glutaraldehyde for 10 min and the other group was exposed to sterilization by UV irradiation. The authors stated that as chemical disinfection leads to a rougher impression surface, UV irradiation sterilization of PVS elastomeric impression materials may be regarded as a more effective method. In our study, following application of different chemical disinfectants to PVS, the lowest surface roughness values were found in the group exposed to quaternary ammonium-based disinfectant.

In a study by Ahila *et al*.[20] where they evaluated the effect of various disinfectants on gypsum casts retrieved from addition and condensation silicone impressions disinfected using spray and immersion methods, disinfection methods did not cause significant changes in the dimensional stability and surface roughness of gypsum casts obtained from impressions.

Kotha *et al*.[21] compared surface roughness of five different PVS impression materials by dividing them to four experimental groups as group I, control; group II, chemical disinfection; group III, autoclave sterilization and group IV, microwave sterilization. Autoclave sterilization and chemical disinfection were found to have no significant effect on surface roughness, but microwave sterilization resulted in increased surface roughness. In contrast, significant changes occurred in surface roughness with the use of different chemical disinfectants.

In one study, Hsu *et al*.[22] investigated the impact of four different, commercially available disinfectants on surface roughness of acrylic resins used in orthodontic appliances, since disinfection of orthodontic acrylic resins can change the physical and mechanical characteristics of these materials. The CaviCide disinfectant was found to cause considerably more surface roughness compared to control but the difference in surface roughness was clinically non-significant. Contrastingly, the CaviCide disinfectant produced significantly less surface roughness in immersion materials tested than NaOCl applied for different durations in our study.

Rose *et al*.[23] compared surface details and dimensional stability of polyether, polyvinyl siloxane, and vinyl siloxane ether impression materials and observed that newer vinyl siloxane ether material showed greater dimensional stability and better reproduction of surface details than polyether and polyvinyl siloxane. In our study comparing surface roughness among the newer vinyl siloxane ether material, polyether, and vinyl siloxane, PVS exhibited significantly less surface roughness.

Hummudi *et al*.[24] investigated the effect of natural disinfectant solutions (apple vinegar and lemon juice) on surface roughness of zinc oxide eugenol (ZOE) impression material and reported that immersion of ZOE in apple vinegar and lemon juice solutions affected surface roughness unfavorably at 10 and 15 min.

Vrbova *et al*.[25] examined the effect of disinfectants on the accuracy, quality, and surface structure of impression materials (elastomeric and alginate) and gypsum casts and found greater deterioration and morphological changes in alginate compared to elastomeric materials. Consistently, among elastomeric materials tested in our study PVS materials were least affected by disinfectants in terms of surface structure.

The sensitivity of SARS-CoV-2, the virus responsible for the current global pandemic COVID, was examined in a study by Ogilvie *et al*.[26] For this purpose, they conducted suspension tests against SARS-CoV-2 using three quaternary ammonium compound (Quat) disinfectants and a 0.2% benzalkonium chloride solution prepared in a laboratory. The authors reported that the Quats rapidly inactivated SARS-CoV-2 and therefore, they may be useful for controlling SARS-CoV-2 spread in the community and hospitals.

In the aforementioned study by Farooqui *et al*.[1] comparing surface roughness of two polyvinyl siloxane impression materials after UV irradiation and chemical disinfection, it was suggested that UV irradiation sterilization of polyvinyl siloxane elastomeric impression materials may be preferred over chemical disinfection, since it causes less surface roughness. Since various chemical disinfectants are still most commonly used for disinfection today, widely available chemical disinfectants and those resulting in the least surface roughness were evaluated in the present study.

Limitations

As impression samples come into contact with the shiny glass surface while taking impressions, their surfaces are quite smooth. However, intraoral structures are complex and there may be differences between the data from *in vitro* studies and data from clinical studies due to the presence of saliva and roughness that occurs while taking the impression out of the mouth.

Conclusions

Among the conventional impression materials tested, polyvinyl siloxane impression material exhibited ideal

properties by showing the lowest surface roughness values. EPA-certified disinfection products are more advantageous as they cause less surface roughness in impression materials. Further studies are needed to test surface roughness of polyether and VSE using different, contemporary methods. *In vitro* and *in vivo* studies using several disinfectants and different techniques for measuring surface roughness would help determine the most appropriate disinfection method that minimizes surface roughness.

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Conflicts of interest

There are no conflicts of interest.

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