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The effect of current infection control procedures and application times on the dimensional stability of dental impression materials

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ABSTRACT

Aims: In this study, the effects of different disinfection and sterilization methods and their application duration on the dimensional stability of impression materials were evaluated.

Methods: Two impression materials, condensation (CS) and addition silicone (VPS), disinfectants with 5.25% sodium hypochlorite (NaOCl) immersion, 3% hydrogen peroxide immersion and steam autoclave were selected. Disc-shaped samples (n=112) were obtained in 7 subgroups of each material (n=8). Sixteen untreated samples served as controls. Dimensional change was measured with a digital micrometer in the reference lines on the sample.

Results: The highest mean percentage of dimensional change for the 50 min autoclave was 0.10±0.03% for CS and 0.10±0.02% for VPS. The dimensional change in CS did not differ for hydrogen peroxide. Compared with the controls, dimensional change was significant in 20 min NaOCl and 50 min autoclave ($p<0.05$). Both impression materials in the autoclave showed statistically significant dimensional changes regardless of the time. The difference in application duration significantly affected the dimensional stability of the impression materials regardless of the procedure ($p<0.001$). Extended application duration did not affect the dimensional stability in the hydrogen peroxide for CS, NaOCl and autoclave for VPS.

Conclusions: Chemical disinfection and autoclave sterilization caused statistically significant but clinically acceptable dimensional changes in CS and VPS impression materials used in this study.

Introduction

Impression is a critical step in prosthetic rehabilitation procedures, such as fixed partial dentures, removable dentures, and implant-supported dentures (1). Microorganisms in the body fluids like saliva and blood cause contamination of the impressions used in prosthetic treatments. Immediately after removing the impression from the mouth, it should be washed under tap water. This process partially eliminates bacteria and viruses but does not eliminate the potential for infection by itself (2). Therefore, disinfection of impressions is a mandatory practice. The American Dental Association (ADA) recommends the disinfection of impressions immediately after removal from the mouth to prevent cross-infection between the patient, dentist, assistant staff, and laboratory staff (3).

In December 2019, a coronavirus, Severe acute respiratory syndrome-Coronavirus-2 (SARS-CoV-2) was identified as a cause of pneumonia in humans (4). The World Health Organization Coronavirus disease-2019 (COVID-19) guidelines were published following the announcement of the pandemic, which included preventive measures and infection control procedures in addition to the possible case definitions in this guideline (5,6). The transmission by droplets and aerosols creates a high risk, especially in dental practice, in terms of the spread of the disease due to cross-infection, and disinfection/sterilization of materials and materials is critical (7).

Various disinfection methods are used in the disinfection of impression materials. The use of chemical methods are most common as they can be applied by spray or immersion methods.

Disinfectants such as glutaraldehyde, sodium hypochlorite (NaOCl), iodophors, phenols, chlorine compounds, and hydrogen peroxide are also used at different concentrations and times. Methods such as microwave, ultraviolet (UV) light radiation, steam autoclave, s ozone, and electrolyzed oxidizing water are other methods applied as infection control protocols (8).

Both NaOCl and hydrogen peroxide are widely used in dental practice as low-cost and effective surface disinfectants. NaOCl is a water-soluble disinfectant. When dissolved hydrochloric acid and oxygen atoms are released, resulting in effective and broad-spectrum antimicrobial results with its oxidizing effect (9,10). Hydrogen peroxide, on the other hand, affects bacterial spores, viruses, and fungi with its enhanced oxidative effect (11).

Disinfectant solutions should be prepared and used according to the manufacturer's recommendations. The United States Environmental Protection Agency (US-EPA) has recommended disinfectants against SARS-CoV-2 and the effective application duration (12,13). According to the US-EPA, hydrogen peroxide should be applied for 5 min and NaOCl for 1-5 minutes to be effective against SARS-CoV-2.

Unlike disinfection, sterilization ensures the elimination of all microorganisms. Although there is no universally accepted sterilization method, the autoclave has been considered the most effective method (14). It also eliminates bacteria, viruses, and spores that are difficult to eliminate with chemical disinfectants (15).

Silicone-based impression materials, which are elastomeric impression materials, are of two types: condensation (CS) type silicones (C type silicone) and addition type silicone (A type silicone/vinyl polysiloxane). Despite the high elasticity of C-type silicones that were developed earlier, dimensional shrinkage occurs because of the subsequent evaporation of ethyl alcohol (16). In contrast, no by-product is formed, and the dimensional accuracy and stability of the A-type silicones are high (17).

Many studies have evaluated the dimensional stability of different impression materials using different chemical disinfection methods (8,10). However, studies on the autoclave procedure during the pandemic particularly relate to protective equipment sterilization. A few studies have evaluated the effects of autoclaves on the dimensional change of dental impression materials. The results of these studies show differences according to variables such as disinfection method, duration, type of impression material, and disinfectant concentration (18,19).

The aim of this study was to investigate the effect of different infection control methods, which have been published as effective on SARS-CoV-2, on the dimensional stability of silicone-based impression materials at varying application durations. The null hypothesis was that different infection control procedures and application durations could show no effect on the dimensional stability of the impression materials tested.

Methods

Two different elastomeric impression materials and three different disinfection procedures were used. Impression materials were CS-type silicone (Zetaplus, Zhermack, Italy) and addition-type silicone (VPS) (Panasil Putty Fast, Kettenbach GmbH, Germany) (Table 1). They were subjected to 5.25% NaOCl (Chloraxid, Cerkamed, Poland), 3% hydrogen peroxide (Oxivir CE Plus, Diversey, Inc, Fort Mill, NC, USA), and a steam autoclave. Application durations were 10 and 20 min of immersion for disinfectant solutions and 40 and 50 min for autoclave. For each impression material, 56 samples were produced and randomly divided into 7 groups (n=8), totaling 112 samples. Controls were formed by taking random samples not subject to any disinfection procedure. Table 2 displays the groups and procedures. Samples were standardized in accordance with specification number 19 of ADA and the ISO 4823:2000 protocol (20). According to this protocol, a stainless-steel mold was formed, and three parallel horizontal 20-µm-wide lines and two vertical 75-µm-wide lines were prepared on the inner surface of the mold (Figure 1). Before producing the samples, the mold was washed twice with ultrasonic deionized water to prevent possible surface contamination.

Mixing of the impression materials was performed in accordance with the manufacturer's recommendation. Samples were prepared manually mixing the base and catalyst, and the impression material was applied to the standard cavity in the mold. A glass plate covered with a thin layer of polyethylene was placed on the mold, and a 1-kilogram weight was placed on the plate. By exposing the sample to a constant force, the pressure applied by the dentist to the impression tray in the clinical practice was simulated. For the polymerization reaction, the sample assembly was immersed in a 35 °C water bath to simulate the existing temperature with the mouth open. The residence time in the water bath was determined as the polymerization time according to the manufacturer's recommendations (3:30 min for CS, 2:00 min for VPS), and an additional 2 min was added to ensure complete polymerization. The polymerized samples were carefully removed from the water and separated from the mold. This process was repeated until 56 pieces of each impression material were obtained. The samples were washed under tap water for 15 seconds and dried with compressed air spray. For each impression material, 7 subgroups were created and 14 groups were numbered. The first 16 samples formed the control group and no disinfection procedure was applied to these samples. NaOCl immersion, hydrogen peroxide immersion, and autoclave procedures were applied to the remaining samples for the times indicated in Table 2. Subsequently, the samples were washed once more under tap water for 15 seconds, and the remaining water was removed with a compressed air spray.

Immediately after the disinfection and sterilization procedures, measurement was performed to calculate the

dimensional change. Linear measurements were made with a digital micrometer using the reference distance on the models. This reference distance was the vertical line (A) in the middle between the two horizontal lines (Figure 1). All measurements were performed 30 min after sample fabrication. After the measurements in the mold, the test samples were separately measured, and the percentage dimensional change was calculated for each using the ISO 4823:2000 formula:

$$\Delta L = \left(\frac{L1 - L2}{L1}\right) X\ 100$$

L1 indicates the measurement of the distance on the mold, and L2 indicates the measurement of the distance on the samples.

Statistical Analysis

Statistical analyses were performed using PSPP (GNU pspp 0.10.4-g50f7b7) and Microsoft Excel programs. The Shapiro-Wilk test was used to test the normality of distribution. To evaluate the effects of the three different infection control procedures on the dimensional stability of impression materials a Two-Way ANOVA test (post-hoc: Bonferroni) was performed. $p<0.05$ was considered significant.

Results

The dimensional change after disinfection occurred in the form of shrinkage in all samples (Table 3). There was a significant difference between CS and VPS regarding the dimensional changes in all disinfection procedures (Figure 2). The highest mean dimensional change (%) occurred in the 50 min autoclave group (0.10±0.03% for CS and 0.10±0.02% for VPS), while the lowest dimensional changes occurred in the control group (0.06±0.02% for CS and 0.02±0.01% for VPS). Different application durations significantly affected the dimensional stability of the impression materials regardless of the disinfection procedure ($p<0.001$).

Regardless of the application duration, the dimensional change of CS did not differ significantly for hydrogen peroxide treatments compared to the control group. Additionally, the dimensional change was statistically significant in all autoclave groups and 20 min NaOCl group compared to the control group

Table 1. Impression materials used and their properties

Impression material	Type	ISO 4823	Mixing technique	Operation time (23 °C) (min:sec)	Hardening time in the mouth (35 °C) (min:sec)	Brand
Panasil putty fast	Addition type silicone	Tip 0, putty	Manual, 1:1 scale (base and catalyst)	2:00	2:00	Kettenbach GmbH, Germany
Zetaplus	Condensation type silicone	Tip 0, putty	Manual (base and catalyst)	1:15	3:30	Zhermack, Italy

Table 2. Experimental groups for each measurement item

Group	Method and time	Number of samples (n)
Control	-	8
3% hydrogen peroxide	10 min immersion	8
3% hydrogen peroxide	20 min immersion	8
5.25% sodium hypochlorite	10 min immersion	8
5.25% sodium hypochlorite	20 min immersion	8
Autoclave	40 min at 134 °C	8
Autoclave	50 min at 134 °C	8

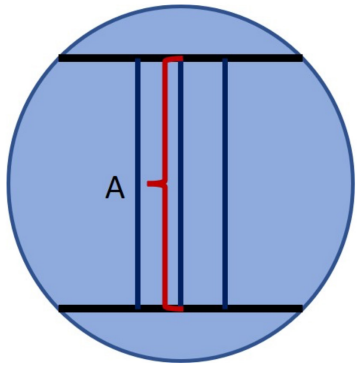

Figure 1. Schematic view of the test setup. Distance "A" (the vertical line in the middle between the two horizontal lines): 25 mm

(p<0.05). Disinfection with NaOCl did not affect the dimensions of the VPS groups, while there was a significant difference in the dimensions in both the 40 and 50 min periods in the autoclave process (Table 3). The autoclave method caused dimensional changes in both impression materials regardless of the application duration.

Two-Way ANOVA was used to evaluate the effect of the disinfection method and application duration on dimensional changes within impression material groups. In the CS group, longer application duration significantly increased the dimensional change (p=0.0001). The prolongation of the time in the VPS groups did not affect the dimensional change in the NaOCl and autoclave groups, while there was a significant difference between the 10 min and 20 min application durations in the hydrogen peroxide group (p=0.02).

When the dimensional changes in impression materials were compared with each other regarding the disinfection method, dimensional changes of CS were significantly higher compared with the VPS in disinfection with NaOCl (p<0.05). There was no significant difference between the dimensional changes of the two impression materials by the autoclave method.

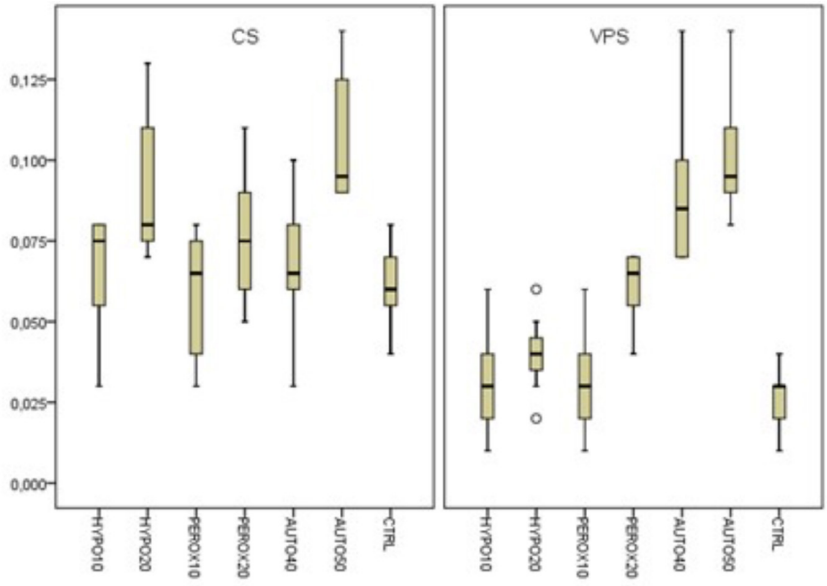

Figure 2. Average dimensional change (%) for the tested procedures
CS: Condensation silicone, VPS: Vinyl polysiloxane

Table 3. Descriptive and statistical analysis

	Dimensional change (%) Mean±SD		p	p**
CS	T_1	T_2		
Hypochlorite	0.07±0.02[1.a]	0.09±0.02[a.2]	0.49	
Peroxide	0.06±0.02[3]	0.08±0.02		**0.0001***
Autoclave	0.07±0.02[b]	0.11±0.02[b]	**0.02**	
Control	0.06±0.01			
VPS				
Hypochlorite	0.03±0.02[1]	0.04±0.01[2]		
Peroxide	0.03±0.02[3.c]	0.06±0.01[c]	**0.02**	**0.001***
Autoclave	0.09±0.02	0.1±0.02		
Control	0.03±0.01			
	p=0.005⁺	**p=0.0001⁺**		

Within any column means with the same superscript numbers are significantly different (p<0.05).
Within any line means with the same superscript letters are significantly different (p<0.05).
⁺Significance between CS and VPS groups.
*Significance within CS and VPS groups.
**Two-Way ANOVA (post-hoc: Bonferroni).
CS: Condensation silicone, VPS: Vinyl polysiloxane, SD: Standard deviation, T_1: 10 min for hypochlorite and peroxide, 40 min for autoclave; T_2: 20 min for hypochlorite and peroxide, 50 min for autoclave

Discussion

Current literature indicates that SARS-CoV-2, the cause of COVID-19, remains as an aerosol for 3 hours and on plastic and steel surfaces for 2-3 days (21). SARS-CoV-2 is a virus with an outer lipid envelope making it more susceptible to disinfectants. Studies on Beta coronaviruses, including SARS-CoV-2, show that these viruses are sensitive to UV light and high temperatures (30 min, 56 °C) (22). The dimensional stability of both impression materials tested in the current study was affected by infection control procedures and different application durations. Hence, the null hypothesis was rejected.

This *in vitro* study was conducted by choosing two previously used disinfection procedures that had been reported effective in SARS-CoV-2 (14). The findings are considered valuable concerning protection from high contamination risk in oral and dental health services. The results showed that the dimensional stabilities of CS and VPS were most affected by the autoclave method, while the prolonged exposure time only affected the dimensional change of CS. According to ANSI/ADA specifications, dimensional changes of less than 0.5% are acceptable (23). No material in this study showed the percentage of dimensional change above this value.

CS is obtained by cross-linking polycondensation reaction, which releases alcohol that contributes to the shrinkage of the impression. This shrinkage increases with the prolongation of time after removal from the mouth. However, VPS has the added benefit of no polymerization shrinkage since no by-products are released (24). This study also confirmed that VPS remained more dimensionally stable than CS due to its chemical structure.

The immersion of elastomers in liquids for a longer duration can lead to dimensional changes due to their hydrophilic nature (9). Moreover, NaOCl is a highly reactive element and may adhere to constituents of the impression material (14). CS and VPS are known as hydrophobic within the elastomeric impression materials. This study explored the causes of why the dimensional changes in CS were significant in the hypochlorite group. However, the previous work stated that the interaction between the NaOCl and the impression material might create a kind of sealing or reduce the dimensional change over time (25). This finding can be considered a beneficial effect of disinfection by immersion in 5.25% NaOCl for 10 min on VPS and could explain the results of our study.

Wetness duration on the applied surface, in other words, the evaporation time of the product from the surface to neutralize viruses and pathogens for any disinfectant, is also extremely important. The evaporation of many disinfectants before the required wet time causes the contaminated surface to be not disinfected at the desired level. This creates the need to apply the product to the surface multiple times to achieve the targeted effectiveness (26). Similarly, immersion of impression materials in different disinfectants in chemical disinfection processes is more effective than spraying their surfaces (8). This may be due to the guaranteed disinfection of all impression surfaces, as well as to the longer exposure time to the disinfectant by immersion rather than spraying (27). However, spray disinfection is preferred, especially for hydrophilic impression materials (28). The solution immersion method will promote the water absorption phenomenon in hydrophilic impression materials, and chemical interactions may occur between the impression material and the disinfectant, especially in long-term applications. The immersion method can be safely preferred for disinfecting hydrophobic elastomeric impression materials such as CS and VPS that were used in the current work. The immersion time of these materials can be longer, as was reported previously (29).

A previous study reported that direct disinfection after water washing reduces microbial contamination but does not change the dimensions of the impression and recommended a 2-step disinfection procedure (water washing + disinfection) (10).

The 10-minute immersion method in 5.25% NaOCl, also chosen in this study, is a disinfection method frequently used in dental practice. It has been reported in previous studies that NaOCl, which has virucidal, fungicidal and bactericidal properties, provides adequate disinfection at this concentration and time (30). Additionally, a previous study has suggested that a 10-minute immersion time in different disinfectants is appropriate (31). The times used in our study are below the ADA-recommended maximum immersion time of 30 min (3). Silva and Salvador reported that immersion of CS in 1% NaOCl for 10 and 20 min did not cause dimensional changes in the material (32). Also, another stud showed no significant expansion in VPS when disinfected by immersion in different chemicals for 10 min or 1 h (33). In the current work, 5.25% NaOCl caused a significant dimensional change in CS in 10 and 20-minute applications, and dimensional stability was not affected in VPS compared to the control group at either application duration. Many studies have reported that the VPS impression material does not undergo dimensional changes when disinfected with NaOCl (34,35). Additionally, the findings here showed that a longer application duration in all disinfection methods in the CS group significantly increased the dimensional change and a significant difference was observed between the 10-minute and 20-minute application durations only in the hydrogen peroxide group in the VPS group.

Disinfection with hydrogen peroxide has been less investigated in the literature. However, a published study highlighted that it is effective in CS and reduces microbial spread (36). This study also found no significant difference in the dimensional change regardless of the disinfection time of CS with hydrogen peroxide. The current findings suggest that hydrogen peroxide might be a disinfectant option for silicone impression materials, while hypochlorite is more suitable for VPS.

Previous authors have emphasized that CS and VPS can be sterilized in an autoclave with a metal standard impression tray at 132 °C (37) without significant dimensional change or at 134 °C (38) with less than 0.5% dimensional change. During the sterilization of the VPS in the autoclave, the dimensional change was significant when measured immediately after the autoclave, but there was no change in 24-hour measurement. Gothwal et al. (39) showed that CS and VPS elastomeric impression materials can withstand higher sterilization temperatures by steam autoclaving at 134 °C for 30 min, without significantly affecting their elastic recovery. Conversely, in this study, possibly due to increased application durations, the autoclave sterilization showed the highest dimensional change values for both impression items, and this finding is similar to the study by Martins et al. (14). However, information on the effects of autoclave sterilization on the dimensional change of the impression is insufficient. As a result, since SARS-CoV-2 is sensitive to high temperatures, it can be predicted that the autoclave method may be successful against the virus, but it may change the dimensions of the measure.

When the dimensional changes of impression materials were compared with each other, CS showed more dimensional changes upon disinfection with NaOCl and hydrogen peroxide. Similar results were obtained with the autoclave method. In this context, current data also confirm that VPS is more dimensionally stable.

Study Limitations

This study has some limitations. The materials tested were not exposed to some conditions that could affect the size of the impression, including moisture in the oral environment, saliva, and removal of the impression from the mouth. Therefore, there may be a disadvantage in fully simulating the clinical environment. Additionally, making the measurements only on a flat surface without assessing three-dimensional dimensional changes can be considered another limitation. The polymerization stages of impression materials were created in the test setup similar to the clinical environment, and the influencing factors were minimized.

In summary, the effect of disinfection or sterilization on the impression varies with factors such as the method used, time, disinfectant concentration, and the type of impression material. Generally, disinfection can affect not only the dimensional stability but also the surface properties of the plaster model obtained from the impression. Therefore, there is a need for future studies that can contribute to the data of this study and evaluate other different clinical parameters.

Conclusions

The percentages of dimensional change in impression materials were clinically acceptable; VPS was more dimensionally stable than CS. Since NaOCl does not affect the dimensional change of VPS, it is preferred over hydrogen peroxide in the disinfection of this material at the recommended times. Hydrogen peroxide did not cause significant dimensional changes in CS. Autoclave sterilization significantly affected the dimensional changes in both impression materials. The prolongation of the application duration correlated with the dimensional changes in CS.

Ethics

Ethics Committee Approval and Informed Consent: This was an experimental study that used *in vitro* environment.

Peer-review: Externally and internally peer-reviewed.

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