



EVALUATING THE IMPACT OF OZONATED WATER DISINFECTION ON THE PHYSICAL PROPERTIES OF POLYVINYL SILOXANE DENTAL IMPRESSION MATERIAL: AN IN VITRO ANALYSIS

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Abstract

Aim: The purpose of this study is to assess the influence of Ozonated water, Microwave irradiation and Glutaraldehyde disinfection techniques on the hardness, compressive strength, and surface roughness properties of Polyvinyl Siloxane impression material.

Material and methods: Forty standardized disc specimens of Polyvinyl Siloxane (10 mm by 3 mm) were fabricated. Assigned as ten discs ($n=10$) to each of four groups, namely; Group I Control (no disinfection), Group II Ozonated water (0.5 ppm/10 min), group III Microwave irradiation (650 W/5 min), and Group IV 2% Glutaraldehyde (10 min). Measurements were taken on, Hardness (N/mm^2), Compressive strength (MPa) and Surface roughness (Ra). To compare the data, one-way ANOVA and the post hoc test ($p<0.05$) of Tukey were applied.

Results: Statistical analysis was done. Hardness and Compressive strength differed significantly among groups ($p < 0.05$). The Control group showed the highest values (hardness: $68.83 \pm 1.02 N/mm^2$; compressive strength: $32.82 \pm 2.38 MPa$). The glutaraldehyde group recorded the lowest ($63.15 \pm 1.77 N/mm^2$; $26.33 \pm 1.48 MPa$). Microwave ($65.34 \pm 1.40 N/mm^2$; $29.50 \pm 3.68 MPa$) and Ozonated water ($65.16 \pm 1.74 N/mm^2$; $29.06 \pm 3.24 MPa$) produced moderate reductions. Surface roughness did not vary significantly between groups ($p = 0.34$).

Conclusion: The Ozonated water and the Microwave irradiation methods are effective disinfection alternatives to Glutaraldehyde, which do not affect the physical properties of Polyvinyl siloxane material.

Keywords: Ozonated water, Microwave irradiation, Glutaraldehyde, Polyvinyl siloxane, Hardness, Compressive strength, Surface Roughness.

Introduction

Dental impressions are crucial for accurate models and clinical outcomes. Despite the popularity of digital scanning, dental impressions are still often utilized in clinical practice. Intraoral scanners are still expensive and less available to dental practitioners and as such, in most dental practices,

conventional impressions are still the preferred method ¹. Failure to use proper disinfection protocols may lead to cross-contamination of patients, clinicians, and laboratory personnel through impressions ². Ozone has now become one of the new alternative disinfectants in dentistry ³. Polyvinyl siloxane impression material is mostly used for the accuracy of prosthetic restorations due to its excellent dimensional stability and reliable physical properties ⁴.

Disinfection of impressions is necessary to avoid cross-infection. However, the concern lies in ensuring that disinfection procedures do not compromise materials desirable properties ⁵. Conventional chemical disinfectants have been reported to alter the mechanical and surface characteristics of impression materials, potentially affecting the accuracy of prosthetic restorations ⁶. Ozone, an allotropic form of oxygen, has a wide range of activity in food industry, medicine, and dentistry ⁷. Ozonated water has drawn interest recently as a potentially effective dental disinfection. Available in aqueous and gaseous forms Ozone has broad-spectrum antibacterial effect against bacteria, fungi, viruses, and protozoa, and is a potent oxidizing agent ^{8,9}. Because ozonated water breaks down into oxygen without leaving any toxic residues, it is both ecologically friendly and biocompatible, which makes it very appealing. Oxidative destruction to microbial cell walls, membrane lipids, proteins, and nucleic acids is the main mechanism by which it disinfects, causing microbial inactivation to occur quickly ¹⁰.

This study provides a direct comparison of three disinfection techniques: Ozonated water, Microwave irradiation, and 2% Glutaraldehyde, and provides quantitative data on the physical properties of polyvinyl siloxane (PVS) impression materials ¹¹. It opens avenues for further research into alternative, eco-friendly, and non-toxic disinfectants in dentistry ¹².

1. Methodology

1.1. Study design and sample size: A comparative experimental study was done in-vitro on forty standard polyvinyl siloxane (PVS) discs (n = 40). There was a random selection of the specimens into four groups (n= 10 each) based on the disinfection.

1.2. Specimen preparation: A standardized stainless-steel mold (10 mm diameter × 3 mm thickness) was used to create PVS discs. To guarantee uniformity, all specimens were examined for flaws, and their dimensions were confirmed using a digital caliper.

1.3. Disinfection protocols

- **Group I:** Control (no disinfection)
- **Group II:** (Ozonated water): Generated by a Faraday Ozone Water Unit (Faraday Instruments, India, GITAM University). Specimens were submerged in Ozonated water (0.5 ppm) for 10 minutes as recommended ¹³. (Figure 1)
- **Group (III) :** (Microwave): For the microwave irradiation samples a domestic microwave oven operating at (650 W for 5 min) was used ¹⁴. To ensure even heat dispersion, samples were put in a glass container that was suitable to use in a microwave and filled with distilled water.
- **Group (IV):** (2% Glutaraldehyde). The specimens were immersed in 2% Glutaraldehyde disinfectant solution for 10 minutes at room temperature ¹⁵.

1.4. Procedure

The samples were allowed to air dry after being washed with distilled water for 30 seconds following the immersion procedures. All specimens were kept at $23 \pm 2^{\circ}\text{C}$ in sealed, humidity-controlled containers before testing.

➤ **Hardness testing(Nmm²):** A Shore-A digital Durometer was used to measure hardness in accordance with ASTM D2240. Each specimen had three indentations taken at standardized locations (≥ 6 mm apart), and the mean value was computed for analysis.

➤ **Compressive strength testing(MPa):** A universal testing machine (UTM 8801) was used to measure compressive strength. After being positioned between compression plates, the specimens

were loaded at a crosshead speed of 1-2 mm per minute until failed(**Figure:2**). Compressive strength was computed using the maximum load (Fmax), $\sigma = F_{\max} / A$ (expressed in MPa).

➤ **Surface roughness testing (Ra):** A contact Profilometer (**SJ-410 Mitutoyo**) was used to measure surface roughness under regulated stylus settings (**Figure 3**). The stylus was calibrated and operated under standard conditions, at a stylus speed of **0.1–1 mm/s**, and a stylus force of approximately **2-4 mN**. Each specimen had three readings taken from various surface areas, and the mean Ra was utilized for statistical comparison.

2. Result

2.1. Statistical evaluation of study outcome

Data were analyzed using software SPSS version 26(**IBM Corp.**). Mean and standard deviation were calculated. One-way ANOVA was used to compare groups; Tukey's post-hoc test was applied for pairwise analysis. Statistical significance was set at $p < 0.05$.

2.2. Outcome assessment

Hardness (Nmm²): Table 1 shows the comparison of mean hardness values between three disinfection methods to control group .

Table 1: Comparison of means of Hardness (Nmm²)

Group	Mean	SD	f-value	p-value
Control group	68.83	1.02	14.43	0.0001*
Ozonated water	65.16	1.74		
Microwave	65.34	1.40		
2%Glutaraldehyde	63.15	1.77		

Interpretation (Table 1): It shows values on the basis of the F-test (ANOVA) and p-values calculated. The control group (Group I) has the highest degree of Hardness values(68.83 ± 1.02). The F-value (14.43) and $p < 0.0001$ indicate that there is statistically significant difference between the four groups. Meanwhile, the Ozone water(Group II) (65.16 ± 1.74) and Microwave (Group III) (65.34 ± 1.40) treatment resulted in the drop in strength in comparison with the control group. 2% Glutaraldehyde(Group IV) treatment causes a drop in strength (63.15 ± 1.77). The disinfection techniques have substantial impact on Hardness, and it is found that the disinfection of the impression material with Glutaraldehyde softens the material compared to others.

Compressive strength (MPa): Table 2 shows the comparison of mean compressive strength values between three disinfection methods to control group .

Table 2: Comparison of means of Compressive strength(MPa)

Group	Mean	SD	f-value	p-value
Control group	32.82	2.38	5.31	<0.001*
Ozonated water	29.06	3.24		
Microwave	29.50	3.68		
2%Glutaraldehyde	26.33	1.48		

Interpretation: F-value (5.31) and $p < 0.001$ implies that there is significant difference in compressive strength across the groups. The Control group(Group I) has the strongest value (32.82 ± 2.38 Mpa). Meanwhile, the Ozone water(Group II) (29.06 ± 3.24 MPa) and Microwave (Group III) (29.50 ± 3.68 MPa) treatment resulted in the drop in strength in comparison with the control group. 2% Glutaraldehyde(Group IV) treatment causes a drop in strength (26.33 ± 1.48 MPa) producing the most noticeable impact.

Surface roughness (Ra): Table 3 shows the comparison of mean Surface Roughness values between three disinfection methods to control group .

Table 3: Comparison of means of Surface roughness (Ra)

Group	Mean	SD	f-value	p-value
Control group	1.48	0.17	1.17	0.34
Ozonated water	1.66	0.25		
Microwave	1.58	0.27		
2%Glutaraldehyde	1.72	0.20		

Interpretation: The analysis of the data of the surface roughness shows that the F-value (1.17) and p (0.34) do not significantly differ, and their value is below the standards of the ADA specification No. 19 (less than 0.5%), and it proves that disinfection methods do not have much influence on surface roughness. The Control group(Group I) has the lowest value (1.48 ± 0.17 Ra). The Ozone water(Group II) had values of (1.66 ± 0.25 Ra) and Microwave (Group III) (1.58 ± 0.27 Ra). The higher surface roughness values (1.72 ± 0.20 Ra) was shown by the Glutaraldehyde (Group IV) group.

It can be concluded that the best mechanical stability of Polyvinyl Siloxane is observed in the Control group(Group I), which is indicated by maximum Hardness and Compressive strength values. Ozone water(Group II) and Microwave irradiation(Group III) had only moderate effect on reducing these properties, making them relatively safer alternatives for disinfecting elastomeric materials. Conversely, the highest decrease in hardness and compressive strength was recorded at 2% Glutaraldehyde(Group IV). Surface roughness remains largely unaffected by any disinfection method in comparison to Control group.

3. Discussion

3.1 Need for Disinfection Studies

Digital impressions are increasingly replacing traditional materials; however, due to their cost and limited accessibility in remote areas, conventional impressions remain prevalent. Disinfection of impressions is emphasized by professional and international dental organizations in order to avoid cross-infection¹⁶. There is still a persistent infection control gap between the clinic and the laboratory as a result of differences in clinical practices, including the under-disinfection of numerous impressions¹⁷. Dental impressions with saliva and blood can transfer microorganisms, which can transmit infections; washing with water only partially removes these microorganisms.

The American Dental Association (ADA) and the World Dental Federation (FDI) recommend disinfection methods to be followed¹⁸. Advice Sheet A12, produced by the British Dental Association, states that impressions are to be disinfected and it is the responsibility of the dentist¹⁹. A systematic review by AlZain²⁰ has found several discrepancies between the findings of different disinfection studies on the properties of impression materials, indicating that more studies are required. Therefore, finding disinfection techniques that effectively reduce microbes while preserving impression quality is still crucial²¹.

3.2. Ozone as an emerging disinfectant in dentistry

Ozone disinfection have recently gained momentum in dentistry²². Recent studies have indicated that ozone is used for the disinfection of impressions, dental prostheses and appliances as well as dental unit waterlines.^{23, 24}. The latest advancements in ozone delivery methods enhance the safety of operators and ozone procedures become applicable in the routine use of ozone in dentistry²⁵. Its use is in line with green dentistry due to the low chemical risk and the potent infection prevention properties have drawn more attention to it as a new disinfection and therapeutic agent in contemporary dentistry^{26,27}.

Clinically, it has been recommended to use Ozone water as an alternative to 5.25% NaOCl, 2% Glutaraldehyde and as an alternative to 0.525% NaOCl^{28, 29} for the disinfection of Silicone impression materials. It is a potent oxidizing agent that can attack the cell membrane, intracellular enzymes and also the DNA of microorganisms³⁰. A 10-minute immersion of impression material in Ozonated water can reduce the count of microorganisms³¹.

3.3 Importance of standardized disinfection protocols:

According to Poulis et al.³², clinically ozone disinfection is a new method used for the inactivation of bacteria, viruses, fungi, yeast, and protozoa. In a review study by Issac AV et al.,³³ using ozonated water for disinfection, gaseous ozone is found to be more effective. It is important to note that various disinfectants can alter the physical properties of impression surfaces. The WHO suggested Glutaraldehyde as the primary disinfecting agent for various infections worldwide. In 2016, Demajo et al.³⁴ stated that Glutaraldehyde is effective without altering dimensional stability of Silicones. A 10-minute immersion disinfection with 0.5% sodium hypochlorite or 2% glutaraldehyde for elastomeric impressions is considered an appropriate method for disinfecting impressions.³⁵

In the present study, the new method of disinfection, Ozonated water, has been compared with Microwave irradiation³⁶ and Glutaraldehyde disinfection in altering the physical properties of Polyvinyl siloxane impression material. Among the disinfection methods assessed, 2% Glutaraldehyde caused the most notable reduction in the Hardness of Polyvinyl siloxane. Microwave disinfection resulted in only minimal changes in hardness, as the short exposure time and weak interaction between microwaves and the hydrophobic PVS structure prevented thermal or structural degradation. Overall, Glutaraldehyde is the most detrimental to hardness, whereas Microwave and Ozonated water are comparatively safe and preserve the material's surface integrity. Goiato et al.³⁷ explained that the lower hardness value observed in the material disinfected by immersion is due to the absorption of the disinfection solution, which may enhance the material's resiliency.

Among the three disinfection methods evaluated, 2% Glutaraldehyde produced the most significant reduction in the Compressive strength of Polyvinyl siloxane, likely due to the disruption of filler–matrix bonding. Ozonated water disinfection does not significantly reduce the compressive strength of Polyvinyl siloxane because a short contact time does not allow ozone to diffuse into the polymer network or alter the cross-link density, resulting in a negligible impact on compressive strength. Microwave disinfection had a minimal impact on compressive strength, as PVS contains very little free water for microwave energy to act upon, and the short exposure time did not induce thermal degradation.

Ozonated water did not affect the Surface roughness of PVS because it does not significantly alter polymer cross-linking or the surface texture of filler particles. Microwave energy produces negligible thermal changes in the surface layer. Glutaraldehyde exhibits very low reactivity with silicone elastomers. The lack of a statistically significant change in surface roughness following microwave irradiation, ozonated water, and glutaraldehyde disinfection may be attributed to the inherent chemical inertness and highly cross-linked structure of polyvinyl siloxane. In contrast there are other studies, where surface roughness has been significantly affected, particularly by chemical disinfectants^{38,39}.

Ozone water disinfection showed the least dimensional changes and preserved surface details more accurately compared to disinfection with 2% glutaraldehyde⁴⁰. Glutaraldehyde caused the most significant reduction in physical properties. Microwave irradiation and ozonated water maintained properties more effectively. Surface roughness remained stable across all groups, preserving impression detail accuracy. Although numerous invitro studies suggest a promising potential for ozone, well-designed studies on material integrity are further needed to evaluate the effectiveness of Ozone in dentistry^{41,42}.

CONCLUSION

Within the limitations of this study, disinfection with 2% Glutaraldehyde significantly affects the physical properties of Polyvinyl Siloxane impression materials, particularly hardness and compressive strength suggesting that regular use of glutaraldehyde could weaken the mechanical integrity of PVS impressions and impact their clinical accuracy. In contrast, Ozonated water and Microwave irradiation demonstrated minimal impact on hardness and compressive strength properties indicating they are more compatible with the PVS material. Surface roughness remained largely unaffected across all disinfection methods, ensuring preservation of fine detail reproduction. Ozonated water and Microwave irradiation disinfection methods preserved the mechanical integrity of the Polyvinyl siloxane impression material supporting their potential for continued research and clinical application. Recognizing this balance helps clinicians confidently select disinfection methods that ensure safety while preserving impression quality.

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