Comparative Evaluation of Changes in Linear Dimensional Stability and Surface Details of Elastomeric Impression Materials following Immersion in Disinfectant Solutions

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Abstract

Background: Linear dimensional stability (LDS) and Surface detail reproduction (SDR) of elastomeric impression material play a crucial role in fixed prosthodontics.
Aim and Objectives: The aim of this study was to evaluate changes in linear dimensional stability and surface details of elastomeric impression materials (Poly Vinyl Siloxane and Polyether) following immersion in disinfectant solutions (glutaraldehyde (Cidex) 2.45%, sodium hypochlorite (Hypo) 5.25% and Chitosan 1%).
Materials and Methods: A stainless steel mold was made to fabricate the study specimens for non-aqueous PVS and PE elastic dental impression materials. Single mix impression techniques with light-body and putty consistency of two materials were used to prepare the test specimens. The specimens were immersed in glutaraldehyde (Cidex) 2.45%, sodium hypochlorite (Hypo) 5.25% and Chitosan 1% disinfection for 15 min (T1) and 6 h (T2) and 12 h (T3) immersion after which dimensional stability and surface detail reproduction were recorded using digital Vernier caliper and stereomicroscope.
Statistical Analysis: The data were analyzed using the RM ANOVA, unpaired t-test.
Results: Dimensional stability at the T1 time interval showed a significant difference for control and glutaraldehyde (Cidex) 2.45%, sodium hypochlorite (Hypo) 5.25% and Chitosan 1% groups ($P < 0.001$). Similar trends were observed at T2 (6 hours) and T3 (12 hours), with PVS consistently outperforming Polyether. At T2 and at T3, the p value is less than 0.001 ($p<0.001$), highlighting the robust advantage of PVS in maintaining dimensional stability over time in the presence of the disinfectant. SDR of the two materials when compared with in three disinfectant solutions that there is no significant difference observed in glutaraldehyde (Cidex) 2.45%, sodium hypochlorite (Hypo) 5.25% but in contrast Chitosan 1% group showed significant difference ($P = 0.009$).
Conclusion: Choice of disinfectant did not significantly affect the dimensional stability of PVS and Polyether in most cases, but Chitosan 1% demonstrated a significant impact, resulting in higher dimensional stability for polyether compared to PVS.

Keywords: Dimensional Stability, Surface Details, Elastomeric Impression Materials, Disinfectant Solutions, Glutaraldehyde, Sodium Hypochlorite

Introduction

Dentistry is a field that involves the clinician and the patient being exposed to saliva and other infectious material.[1] Contamination of the working atmosphere by microorganisms from oral micro flora in a dental clinic offers constant risks to the health professionals.[2] There is evidence regarding the pathogenesis and intensity of viruses of hepatitis B, herpes, tuberculosis, AIDS and Coronavirus disease 2019 (COVID-19) in dentistry. Close contact with the patient, saliva, blood, spatter and aerosol exposure may cause a risk of transmissible diseases. Impression materials are used in the fabrication of indirect restorative procedures. They often come in contact with the patients saliva and blood, which may lead to them becoming infected. Hence, disinfection of impression materials is important as the dentist, oral hygienist, and dental laboratory personnel are often exposed to infectious diseases.[3,4] Two widely used rubber base materials are vinyl poly- siloxane (also called addition silicone) and polyether which have long been in use in fixed prosthodontics as they result inimproved dental dies due to superior dimensional stability resulting in less marginal inaccuracy.[2]The accuracy and dimensional stability of vinyl polysiloxane and polyether is well documented. Enhancement of hydrophilicity may influence the accuracy of impressions and can result in improved flow and finer detail of impressions made on moist dentinal surfaces and in the area of the gingival sulcus.[5] There are many disinfectant solutions used to disinfect elastomeric impression materials i.e 2% gluteraldehyde, 70% ethanol, 2% chloramine, 0.5% or 3% or 5.25% sodium hypochlorite, sporocidin (0.13% gluteraldehydephenate buffer), deionized water etc. Minagi et al. found that immersion of polyvinyl siloxane in sodium hypochlorite or 2% glutaraldehyde for more than 60 minutes affected linear dimensions and detail reproduction.[2] Bergman et a1. reported no change in dimensional stability and surface detail after immersion of polyether impressions for 1 hour in 2% alkaline glutaraldehyde.[4]Johnson et al. reported good quality of the surface but only fair dimensional stability after 10 minutes soak of polyether in 2% gluteraldehyde and 1% phenol solutions.[2,6,7] Chitosan is a recently introduced disinfectant which is a natural, nontoxic biopolymer of chitin. Chitin is the main component of the cell walls of fungi and the exoskeleton of arthropods such as crustaceans (lobsters and shrimps). Chitosan is being used in dentistry as an implant surface modifier, as a component in dental adhesives, dental composite resins, and in combination with dentifrices and mouthwashes to reduce plaque.[8] So far, in literature we have seen the effect of 2% gluteraldehyde and 3% sodium hypochlorite on condensation silicone and polyether. In this study, we will assess the dimensional stability and surface details of addition silicone and polyether after immersion in 2.45% of gluteraldehyde, 5.25% of sodium hypochlorite and 1% chitosan solution for 10 minutes and test them at three time intervals T1 (15 min) and T2 (6 hour) and T3 (12 hour) after fabrication.Hence the purpose of this in vitro study is to determine the effect of chemical disinfection on dimensional accuracy and surface details of elastomers.

Materials and Methods

A standardized stainless steel (SS) mold customized as per American Dental Association (ADA) specification no. 19 was used for testing of non-aqueous elastomeric impression materials.[7]

The mold comprised three sections:-

Section A-A:-Ruled block which contain three horizontal scribed lines and two vertical scribed lines and act as base.

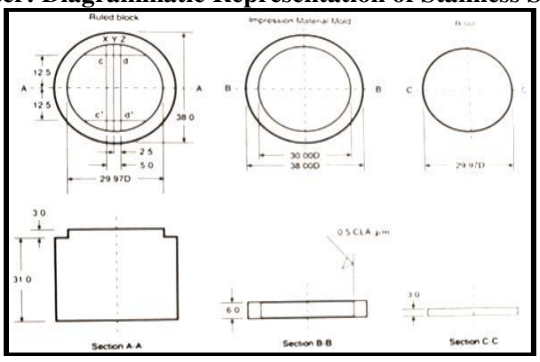
Fig 1- Ruled Block

Section B-B:-Impression material mold is a ring of thickness 3 mm and it holds the impression material.

Fig 2- Impression material mold

Section C-C:-Riser which is perforated plate to apply uniform pressure over impression material, mechanical retention and escape of excess material.

Fig 3- Riser: Diagrammatic Representation of Stainless Steel Mold



The impression materials used in the study were Polyvinyl siloxane impression material- Putty and light body consistency (Orikam Neopure), Polyether impression material-medium body consistency hydrophilic (3M Impregum^{Tm} Soft ESPE). A total of one hundred twenty samples of each test material were made (n=120). Specimens having bubbles and irregularities were discarded. The disinfectants used in the study were Gluteraldehyde – 2.45% (Cidex [Johnson and Johnson, India]), Sodium hypochlorite - 5.25% (NaOCl [Vishal, India]) and Chitosan- 1% (Bangaluru Chem, India). All 120 samples were made and divided into two groups (Group I and Group II) each with 60 samples.

Group I was Polyvinylsiloxane (PVS).
Group II was Polyether (PE).
Group I was further sub divided into three groups i.e. Ia, Ib, Ic according to various chemical disinfectant solutions. Each contained 20 samples. Distilled water was taken as control.

Manipulation of Materials

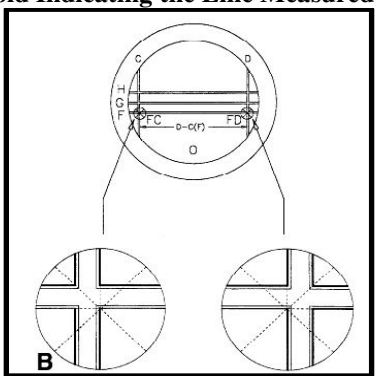
For Polyvinyl Siloxane: Polyvinyl siloxane impression material (light body/ putty, Orikam Neopure) was used in an auto-mixing syringe. Equal proportions of base and catalyst of polyvinyl siloxane putty were taken. The impression materials were mixed according to the manufacturer's instructions. The light body material in an auto-mixing syringe was injected on the ruled block of the mold from the periphery to the center. The entire mold was covered with a coating of light body material, similar to conventional clinical procedures. The putty material was placed over the light body, and the entire assembly (ruled block, impression mold, riser) was kept under a 1Kg weight to standardize pressure during polymerization.[9] To ensure completepolymerization, materials were allowed to set for 10 minutes at room temperature.[7,9] The samples were removed from the master die with a snap and rinsed under tap water for 30 seconds. Each sample was then labelled.

For Polyether: Equal length of base and catalyst paste of Polyether impression material-medium body consistency hydrophilic (3M Impregum^{Tm} Soft ESPE) were taken. The impression materials were mixed according to the manufacturer's instruction. The impression material was loaded on the assembled mold and a 1 kg weight was positioned on top of the assembly to standardize pressure during polymerization.[9] To ensure complete polymerization, material were allowed to set for 10 minutes at room temperature.[7] The impression was removed from the master die with a snap and rinsed under tap water for 30 seconds. Each sample was then labeled. The disinfectants used in the study were glutaraldehyde (2.45%) (Cidex [Johnson and Johnson, India])and sodium hypochlorite (Hypo) (5.25%) (NaOCl [Vishal, India]) and Chitosan 1% (Bengaluru Chem, India). 100 ml of all three disinfectant solutions were kept in three different beakers and the specimens were immersed in these disinfectant solutions for 10 min and tested at three-time intervals T1 (15 min),T2 (6 h) and T3 (12 h) after fabrication. The study groups of the specimens were the control group (n = 20) which were dipped in distilled water, glutaraldehyde group (n = 20) immersed in glutaraldehyde, and NaOCl group (n = 20) immersed in NaOCl and Chitosan group (n=20) immersed in Chitosan.

Measuring of Test Specimens for Dimensional Accuracy

A. **Evaluation of Linear Dimensional Stability :** The samples were evaluated by measurement of the linear dimension of line F from point C to point D, i.e distance between C and D referred to as C-D (F) with the help of a Digital Vernier Caliper after T1- 15 minutes and T2- 6 hours and T3-12 hours.All the specimens were numbered group wise for measuring dimensional accuracy.[9]

Schematic Diagram of Stainless Steel Mold Indicating the Line Measured and Reference Points



B. **Evaluation of Surface Detail Reproduction**
Surface detail reproduction for the control group was done by recording the reproduction of 50 µ line on to samples. Outcomes were recorded as[7]
(a) Line reproduced completely and
(b) Line not completely reproduced
This was used as a quality-control measure. The entire length of the 50 µ was observed at ×10 magnification and given an ordinal score as follows:

Score 1: well defined, sharp, continuous lines;

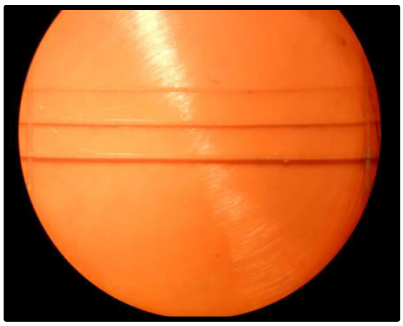


Fig 4- Continuous Lines

Score 2: continuous line but with some loss of sharpness.

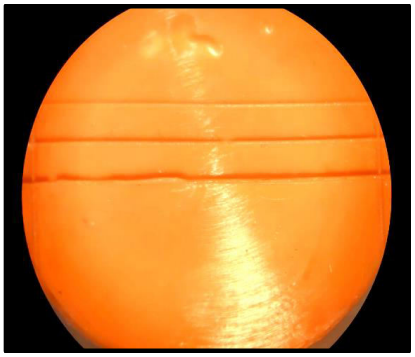


Fig 5- Continuous Lines with Some Loss of Sharpness

Score 3: significant deterioration of edge detail or loss of continuity of the line,

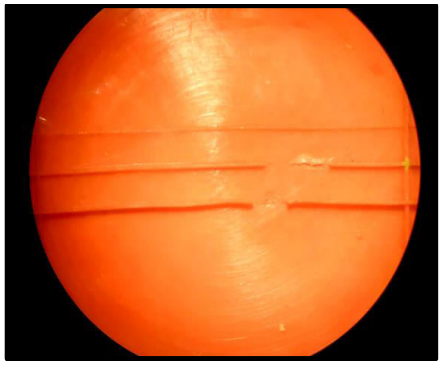


Fig 6- Loss of Continuity of the Line

Score 4: Failure to reproduce the line.

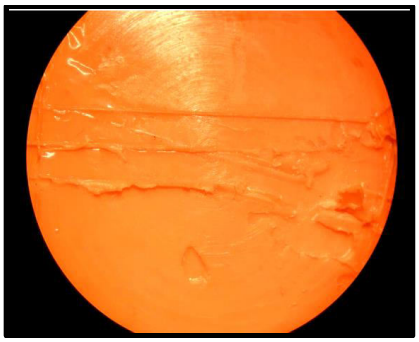
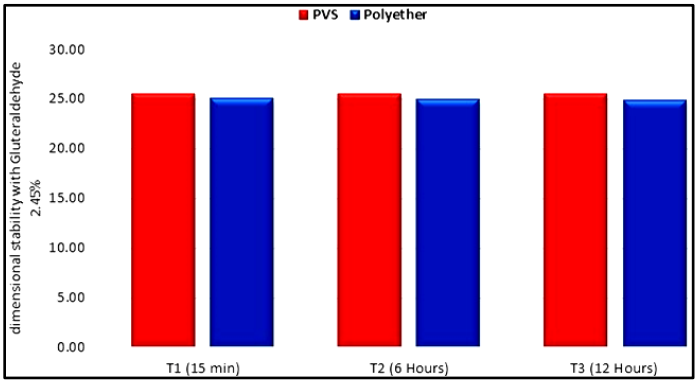


Fig 7- Failure to Reproduce the Line

Results

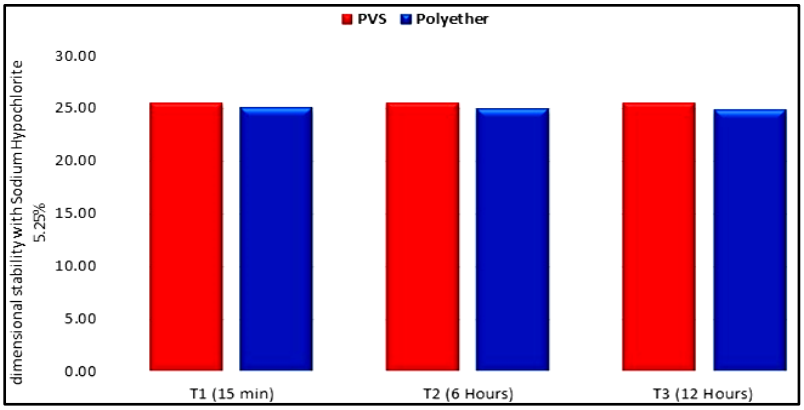
The study evaluated the impact of Glutaraldehyde (2.45%), Sodium Hypochlorite (5.25%) and Chitosan (1%) disinfectant on the dimensional stability of Polyvinyl Siloxane (PVS) and Polyether dental impression materials. The investigation focused on both intergroup and intragroup comparisons across three different time points. For Glutaraldehyde (2.45%), at T1 (15 minutes), T2 (6 hours), and T3 (12 hours), measurements were taken for both PVS and Polyether with the disinfectant. The results showed that, at each time point, PVS exhibited superior dimensional stability compared to Polyether. For instance, at T1, the mean dimensional stability for PVS was 25.63 (SD=0.01), while for Polyether, it was 25.19 (SD=0.05). The unpaired t-test revealed a substantial t-value of 34.60 ($p<0.001$), indicating a significant difference in dimensional stability between PVS and Polyether when subjected to Glutaraldehyde 2.45% at this early time point. Similar trends were observed at T2 (6 hours) and T3 (12 hours), with PVS consistently outperforming Polyether. At T2, the t-value was 34.56 ($p<0.001$), and at T3, the t-value further increased to 64.52 ($p<0.001$), emphasizing the robust advantage of PVS in maintaining dimensional stability over time in the presence of the disinfectant. Intra-group comparisons using repeated-measures ANOVA (RM ANOVA) were performed for both PVS and Polyether. The results demonstrated significant changes within each group over time. For PVS, $F=175.3$ ($p<0.001$), and for Polyether, $F=385.7$ ($p<0.001$), indicating substantial alterations in dimensional stability for both materials across the assessed time points when exposed to Glutaraldehyde 2.45%.



Graph 1- Intergroup & Intragroup Comparison of Dimensional Stability between PVS &Polyther with Disinfectant: Gluteraldehyde 2.45%

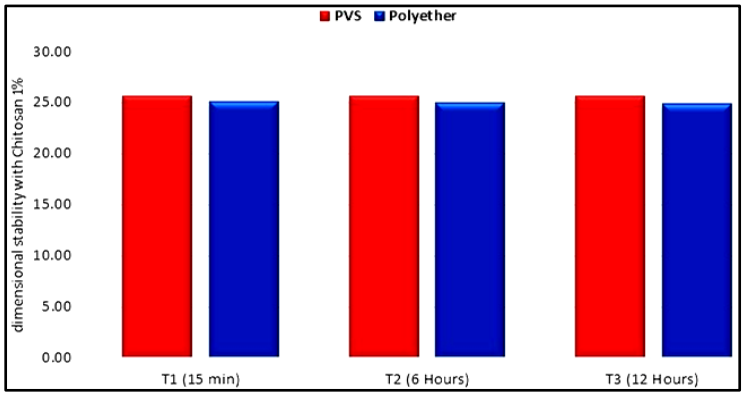
For Sodium Hypochloride (5.25%), at T1 (15 minutes), T2 (6 hours), and T3 (12 hours), measurements were conducted for both PVS and Polyether with the disinfectant. The results indicated that, at each time point, PVS consistently displayed superior dimensional stability compared to Polyether. For instance, at T1, the mean dimensional stability for PVS was 25.60 (SD=0.13), while for Polyether, it was 25.13 (SD=0.03). The unpaired t-test unveiled a substantial t-value of 14.22 ($p<0.001$), signifying a significant difference in dimensional stability between PVS and Polyether when exposed to Sodium Hypochlorite 5.25% at this initial time point. Similar trends were observed at T2 (6 hours) and T3 (12 hours), with PVS consistently outperforming Polyether. At T2, the t-value was 14.96 ($p<0.001$), and at T3, the t-value further increased to 17.37 ($p<0.001$), highlighting the robust advantage of PVS in maintaining dimensional stability over time in the presence of the disinfectant. Intragroup comparisons using repeated-measures ANOVA (RM ANOVA) were performed for both PVS and Polyether. The results

demonstrated significant changes within each group over time. For PVS, F=75.9 (p<0.001), and for Polyether, F=730.3 (p<0.001), indicating substantial alterations in dimensional stability for both materials across the assessed time points when exposed to Sodium Hypochlorite 5.25%.



Graph 2-Intergroup & Intragroup Comparison of Dimensional Stability between PVS & Polyther with Disinfectant :Sodium Hypochlorite 5.25%

For Chitosan (1%), at T1 (15 minutes), T2 (6 hours), and T3 (12 hours), measurements were taken for both PVS and Polyether with Chitosan 1%. The results revealed that, at each time point, PVS consistently demonstrated superior dimensional stability compared to Polyether. For instance, at T1, the mean dimensional stability for PVS was 25.69 (SD=0.12), while for Polyether, it was 25.12 (SD=0.02). The unpaired t-test showed a t-value of 18.99 (p<0.001), indicating a substantial difference in dimensional stability between PVS and Polyether when exposed to Chitosan 1% at this initial time point. Similar trends were observed at T2 (6 hours) and T3 (12 hours), with PVS consistently outperforming Polyether. At T2, the t-value was 20.16 (p<0.001), and at T3, the t-value further increased to 20.89 (p<0.001), emphasizing the robust advantage of PVS in maintaining dimensional stability over time in the presence of Chitosan 1%. Intragroup comparisons using repeated-measures ANOVA (RM ANOVA) were performed for both PVS and Polyether. The results demonstrated significant changes within each group over time. For PVS, F=155.9 (p<0.001), and for Polyether, F=241.4 (p<0.001), indicating substantial alterations in dimensional stability for both materials across the assessed time points when exposed to Chitosan 1%.



Graph 3- Intergroup & Intragroup Comparison of Dimensional Stability between PVS & Polyther with Disinfectant: Chitosan 1%

Time	PVS		Polyether		Significance
	Mean	SD	Mean	SD	
T1 (15 min)	25.64	0.09	25.15	0.05	t=37.4, **p<0.001**
T2 (6 Hours)	25.61	0.09	25.08	0.04	t=42.2, **p<0.001**
T3 (12 Hours)	25.59	0.10	24.96	0.02	t=49.4, **p<0.001**
Intra-group (RM ANOVA)	F=280.1, **p<0.001**		F=599.9, **p<0.001**		

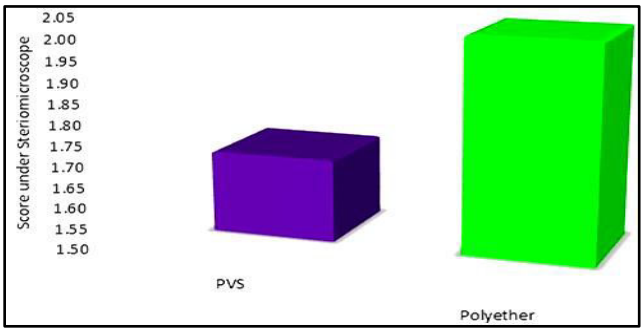
Table 1:- Intergroup & Intragroup Comparisons of dimensional stability between PVS and Polyther Materials

The dimensional stability between PVS and Polyther materials was compared both intergroup and intragroup across three different time points—T1 (15 minutes), T2 (6 hours), and T3 (12 hours). The mean dimensional stability, along with standard deviations (SD), for both materials at each time point was analyzed. At T1 (15 minutes), PVS exhibited a mean stability of 25.64 (SD = 0.09), while Polyther had a mean stability of 25.15 (SD = 0.05). The intergroup comparison using an independent t-test showed a significant difference between the two materials, with t=37.4 and p<0.001. Similarly, at T2 (6 hours), PVS had a mean stability of 25.61 (SD = 0.09), and Polyther had a mean stability of 25.08 (SD = 0.04). The intergroup comparison yielded a significant difference with t=42.2 and p<0.001. At T3 (12 hours), PVS showed a mean stability of 25.59 (SD = 0.10), while Polyther had a mean stability of 24.96 (SD = 0.02). Once again, the intergroup comparison was highly significant, with t=49.4 and p<0.001. For intragroup comparisons within each material over the three time points, repeated measures ANOVA (RM ANOVA) were conducted. For PVS, the F-statistic was 280.1 with p<0.001, indicating a significant difference across time points. Similarly, for Polyther, the F-statistic was 599.9 with p<0.001, signifying a significant difference in dimensional stability over time.

Material	Score under Stereomicroscope		Significance (Mann Whitney test)
	Mean	SD	
PVS	1.70	0.93	z=2.36, **p=0.018**
Polyether	2.02	0.81	

Table 2:- Comparisons of Score under Stereomicroscope between PVS and Polyether Material

The scores obtained under the stereomicroscope for PVS and Polyether materials were analyzed, resulting in mean scores and standard deviations (SD). PVS exhibited a mean score of 1.70 with an SD of 0.93, while Polyether had a mean score of 2.02 with an SD of 0.81. The Mann-Whitney test was employed for intergroup comparison, revealing a significant difference between the two materials. The calculated z-value was 2.36, and the associated p-value was 0.018, indicating a statistically significant distinction in scores between PVS and Polyether materials.



Discussion

Impression materials should reproduce hard and soft tissue in order to obtain biologically, mechanically, functionally and esthetically acceptable restorations. Elastomers primarily referred to as rubber base polymers which physically or chemically are interlinked, showing property of relapsing to original shape when indicated pressure is released.[2,10,11] However, dimensional changes in the mold inherent to the impression material can occur, because of changes in wettability, handling properties, viscosity and thickness of the material existing between the oral structure and tray, fixation method of impression material on tray, time elapsed for cast pouring, material's hydrophilicity, byproduct loss, polymerization shrinkage, thermal shrinkage due to temperature change (from the mouth to room temperature),incomplete elastic recovery and in some cases, soak. Impression quality is influenced by tray selection impression technique and preparation design.[9,11,12,13] After Covid-19 pandemic the use of disinfectant solutions increased so, it is compulsory for the dentist to clean the impression with the help of disinfectant solution and protect doctors and lab personnel from the infectious diseases. Dental patients are the most common source of micro-organisms which causes dental practitioners to encounter potentially

harmful micro-organism. It has been noticed that the outer surface of the impressions when retrieved from the mouth is usually contaminated with bacteria. Micro-organisms are eradicated by chemical disinfection as impressions and occlusal records cannot be sterilized by heat. The ADA recommends soaking impression materials in disinfectant solutions for <30 minute.[7,14,15,16]

In this study a comparison of dimensional stability of Polyvinyl Siloxane (PVS) and Polyether dental impression materials with Glutaraldehyde 2.45% disinfectant at three different time points, that is T1 (15 minutes), T2 (6 hours), and T3 (12 hours). The results were carried out at each time point, PVS exhibited superior dimensional stability compared to Polyether. At T1, the mean dimensional stability for PVS was 25.63 (SD=0.01), while for Polyether, it was 25.19 (SD=0.05). The unpaired t-test revealed a substantial t-value of 34.60 ($p<0.001$), indicating a significant difference in dimensional stability between PVS and Polyether when subjected to Glutaraldehyde 2.45% at this early time point. Similar trends were observed at T2 (6 hours) and T3 (12 hours), with PVS consistently outperforming Polyether. At T2, the t-value was 34.56 ($p<0.001$), and at T3, the t-value further increased to 64.52 ($p<0.001$), emphasizing the robust advantage of PVS in maintaining dimensional stability over time in the presence of the disinfectant. The intra-group comparisons using repeated-measures ANOVA (RM ANOVA) were performed for both PVS and Polyether. The results demonstrated significant changes within each group over time. For PVS, $F=175.3$ ($p<0.001$), and for Polyether, $F=385.7$ ($p<0.001$), indicating substantial alterations in dimensional stability for both materials across the assessed time points when exposed to Glutaraldehyde 2.45%. These findings were in agreement with the study that was conducted by Monika Khatri et. al.[7] which showed that PVS is more dimensionally stable as compared with polyether when immersed in Gluteraldehyde 2.45%. The scores obtained under the stereomicroscope for PVS and Polyether materials were analyzed, resulting in mean scores of PVS is 1.70 with an SD of 0.93, while Polyether had a mean score of 2.02 with an SD of 0.81. The Mann-Whitney test was employed for intergroup comparison, revealing a significant difference between the two materials. The calculated z-value was 2.36, and the associated p-value was 0.018, indicating a statistically significant distinction in scores between PVS and Polyether materials. Hence the surface details reproduction of polyether is more as compared to PVS. The limitations of the present study were that the impressions were made of standardized SS dies which do not resemble the behavior of the oral tissues, and it was an in vitro study. A clinical investigation should be undertaken with different concentrations and types of chemical disinfectants.

Conclusion

Dimensional accuracy of impression materials is of utmost necessity for the production of working models in fixed prosthodontics. Dental impressions provide the reproduction of anatomic and surface details of teeth and adjacent structures which is made possible only when impressions are accurate and when disinfection protocols cause minimum distortion. High level disinfectant solutions (Gluteraldehyde, Sodium Hypochloride, Chitosan) that belong to different chemical groups and different concentrations (2.45%, 5.25%, 1%) did not affect the accuracy and dimensional stability of polyvinyl siloxane and polyether impression materials after immersion for 15 minutes, 6 hours and 12 hours. So it is concluded that these disinfectants can be safely used for disinfection of polyvinyl siloxane and polyether in these concentrations and suggested time intervals. It was also concluded that polyvinyl siloxane showed better dimensional stability as compared with polyether. With regard to surface details reproduction, polyether showed better results with polyvinyl siloxane.

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