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ASSESSMENT OF SURFACE DETAILS REPRODUCTION & DIMENSIONAL ACCURACY OF GYPSUM MODELS RETRIEVED FROM VINYL SILOXANE ETHER IMPRESSIONS AFTER THEIR DISINFECTION

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ABSTRACT

Objectives: *This study aims to investigate the surface details reproduction and dimensional accuracy of gypsum models retrieved from vinyl siloxane ether impression material after treatment with various modes of disinfection of the impression material.*

Materials and Methods: *An observational study was carried out on a total number of 54 vinyl siloxane ether impressions that were subjected to three different modes of disinfection i.e 3 % of Didecyldimethylammonium chloride , submersion in 2 % Glutaraldehyde solution for around 10 minutes and microwave disinfection for 8 minutes .The data analysis was done using , the paired-samples T-Test for the difference in dimensional change between pre and post-treatment of groups, for intergroup comparison, the One-Way ANOVA was used, SPSS version 21 .Numerical data was displayed in form of tables and charts.*

Results: *There was no difference between the surface detail reproduction of gypsum models among the three different methods of disinfection of the vinyl siloxane ether impression as there was 100 % surface detail reproduction in all 3 groups. A significant difference in dimensional accuracy was detected in the gypsum models poured of vinyl siloxane ether treated with microwave disinfection ($p<0.001$) and no significant change was recorded in the dimensional accuracy of groups treated with 3 % Didecyldimethylammonium chloride and submersion in 2 % Glutaraldehyde solution for 10 minutes.*

Conclusion: *Microwave disinfection had a remarkable impact on the dimensional accuracy of gypsum models so it should be used with care.*

Key words: *Gypsum models, vinyl siloxane ether impressions, dimensional accuracy, disinfection, surface details reproduction*

INTRODUCTION

A dental impression can be described as a negative representation of the oral cavity's soft and hard tissues that is used to create dental models and casts[1]. In dentistry, gypsum cast are utilized for a number of tasks, including diagnosis, restoration manufacture, and treatment planning[1,2]. The precision of the impression, which is influenced by a number of variables including the impression tray, impression technique, and the material's dimensional stability, determines the accuracy of the gypsum cast[2,3]. A high-quality dental prosthesis requires a gypsum cast with exceptional surface detail re-production & dimensional accuracy[4].

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Contamination of impressions with blood and saliva, followed by gypsum casts, is a regular occurrence in dentistry[5]. Numerous harmful organisms can be found in blood and saliva, which increases the possibility of cross-infection and the development of major infectious disorders such hepatitis-B/C and Acquired immunodeficiency syndrome (AIDS)[6]. Sterilization and disinfection are two methods that can be used to prevent cross-infection. Simply rinsing dental impressions in water is insufficient to eradicate microorganisms[7]. American Dental Association (ADA) and Center for disease control and Prevention (CDC) advise various measures for infection control to stop the spread of infectious diseases via contaminated casts, impressions, and models. These consist of immersion or spraying with disinfectant, microwave radiation, and various sterilization procedures[6-10].

Common chemical disinfectants include glutaraldehyde and sodium hypochlorite[10]. Impression materials, however, may be negatively impacted by the different infection control techniques.

Due to excellent surface detail reproducing and dimension stability, polyether silicone and polysulfides are the elastomeric impression materials of choice[11,12].

Compared to all other conventional impression materials, vinyl siloxane ether (VSE), a form of impression material, has shown to have greater dimensional stability and improved surface detail replication[13]. Numerous studies have been conducted on the detrimental impact of infection control practices on various types of impression materials[14-18]. When it comes to chemical disinfection, the type of disinfectant and impression material, as well as the length of the disinfection process, determine how the impression's dimensional stability and wettability vary. According to Nassar et al., vinyl polyether silicone (VPES), showed superior accuracy when used in immersion disinfection[5,19]. Similar to this, sterilization was thought to be the best way to clean silicone impression materials, but not hydrophilic impression materials[20]. The techniques utilized to sterilize and disinfect impression materials can affect the wetting ability and dimensions of the materials as well as negatively affect the gypsum casts' ability to reproduce surface details[19]. Gypsum casts produced from condensation silicone impressions and rinsed with sodium hypochlorite, resulted in shrinkage, indicating an appreciable decrease in the dimensional accuracy of these casts[21].

Although widespread evidence on the impact of numerous disinfectants and sterilization techniques on the dimensional stability of impression materials is found in the literature, there is a dearth of research on the surface re-production and dimensional of gypsum casts that are retrieved from vinyl siloxane ether impression materials after being disinfected. Therefore, the primary purpose of this research is to determine the effects of 3% Didecyldimethylammonium chloride, 2% glutaraldehyde, and microwave disinfection of vinyl siloxane ether impression on the gypsum casts' dimensional accuracy and re-production of surface details.

MATERIALS AND METHODS

To conduct a study on dental materials, the Dental Materials Department Laboratory at Khyber College of Dentistry in Peshawar carried out in-vitro research for a period of two months, from October 2023 to December 2023. This research received approval from the Undergraduate Research Committee KCD.

On par with American Dental Association Specification No. 19, a metallic test block was developed specifically for the evaluation of impression materials that fall in the category of non-aqueous elastomers. This test block consists of four parts: a ruled block, an impression material mold, a riser, and a gypsum mold (Figure 1, 2).

The elastomeric impression material used in the study was vinyl siloxane ether (Identium® - Kettenbach, Germany). It had a medium-bodied consistency of type 2 and a fast setting type. A pre-packed cartridge of Identium® - Kettenbach, Germany (1:1, 50ml) was put into a cartridge dispenser (3M-ESPE) coupled with a static mixing tip. The impression was made by placing the mold on the test block and injecting the material onto the die surface in a zig-zag pattern through the tip. To prevent air trap, the tip remained submerged in the material. This process was completed within 45 seconds, which is the recommended working time. A polyethylene sheet was used to cover the mold soon after the injection of the material. A weight of 575g was positioned over it to ensure consistent

pressure during the setting process. The assembled unit was then put in a water bath (Supertek) having a preserved temperature of 32 ± 2°C and left to set. Once the material was set, the impression was taken out from the mold using a riser. Die markings were imprinted on the impression material.

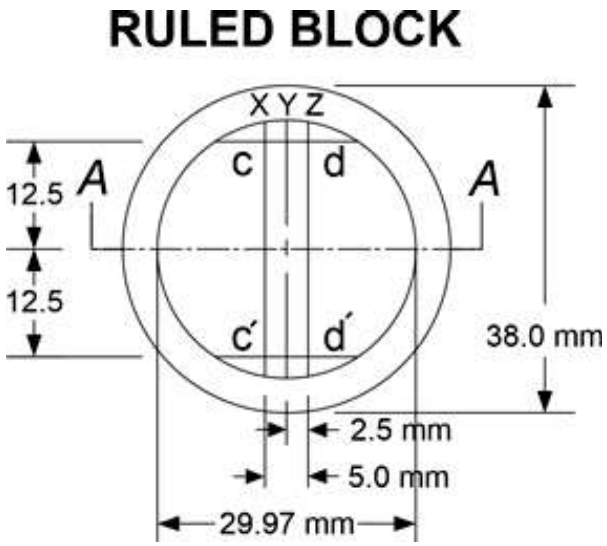

Fig 1: ADA Specification no.19 for ruled block.

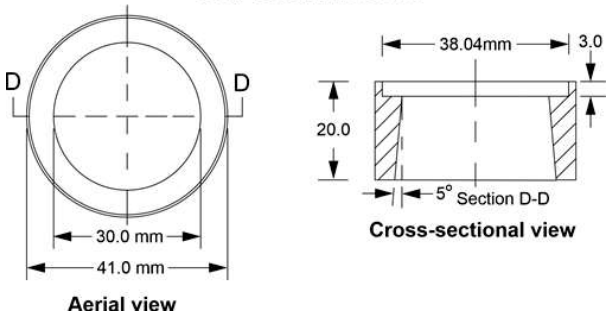

Fig 2: ADA Specification no.19 for gypsum mold.

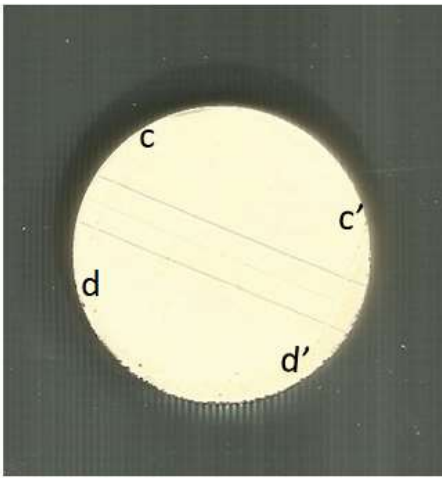

Fig 3: Scanned picture of cast, showing the impression of engraved lines.

A total of 54 impressions were made using vinyl siloxane ether on stainless steel dies. These dies had three vertical lines of varying widths (20 µm, 50 µm, and 75 µm) engraved on the superior surface of the die. Additionally, the ruled block was engraved with two perpendicular lines (c d and c'd') , intersecting the previously mentioned lines (Figure 1).

The separation between the crosslines (c d and c'd') was assessed for all 54 samples, and the readings were recorded as "Pre-treatment readings".

Based on the type of disinfectant applied, the impressions were then segregated into 3 groups. Each group consisted of 18 samples.

Group 1: 3 % of Didecyldimethylammonium chloride (Practice Safe Solution). It is a quaternary ammonium compound and the impression was soaked for 30 minutes. Practice safe soak solution (Kemdent, England), was diluted to the manufacturer's recommended level, which was 3%.

Group 2: Submersion in 2 % glutaraldehyde solution for 10 minutes. For the prevention of air bubbles formation , the dental type 3 (high strength) die stone was mixed for a minute before being put into the gypsum mold against the impression using high frequency vibration. The set gypsum was let off the cast after 30 minutes.

Group 3: Microwave disinfection (8 minutes), Daewoo KOR6L15,#650W Manual Microwave, home use oven was used.

Following the below given method, the separation between the crossline (c d and c'd') was recorded and documented as "post-treatment readings."

Dimensional Accuracy & Surface Detail Reproduction:

A digital scanner, HP Desk Jet 2050 J510 model, was utilized to capture digital images of each individual specimen. The resolution employed for this process was 600 dpi (dots per inch). The software used to analyze these images was the Adobe Reader XI, also known as AcroRd 32. To measure the gap between the crosslines, denoted as c d and c'd', a high level of accuracy was maintained, with measurements recorded down to 0.01mm. Subsequently, a mean value was calculated based on these measurements. Data analysis was conducted using Statistical Package for the Social Sciences (SPSS)

version 27. Data was assessed with a confidence interval 95% and a P-value ≤ 0.05 was regarded significant. In order to determine the difference in dimensional change between pre and post treatment groups, a paired-sample T-test was employed. Additionally, for intergroup comparison, the One-Way ANOVA method was utilized. It should be noted that the ADA specification no: 19 requires dental casts made of vinyl siloxane ether to constantly reproduce a 20 um line in width and having a total length of 25 mm between c d and c'd'22 .The same aforementioned procedure was followed in the analysis of the images. To better understand the reproduction of surface detail, a grading system ranging from 1 – 4 was implemented. In this system, Grade 1 represents a line that is consistently produced throughout the entire length, clear and sharp. A line with a grade 2 is smooth, well-defined, and covers more than half of its length. Grade 3 denotes a line with less than 50% clarity, albeit imperfect and uneven. Lastly, Grade 4 represents a line that is not smooth , damaged, dented and not in continuation, resulting in the flawed appearance among all the grades.

RESULTS

1. Surface Detail Reproduction:

The results of surface detail reproduction of casts after their disinfection are mentioned in table 1.

2. Dimensional Accuracy:

Interpretation of One-Way ANNOVA, since the p value is < .001, It indicates that there is difference

Table 2: Descriptive statistics of post - treatment mean distances for different disinfection methods.

post_treatment_mean_distance								
					95% Confidence Interval for Mean			
Groups	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
Didecyldimethylammonium chloride	18	24.3633	.05739	.01353	24.3348	24.3919	24.27	24.45
gluteraldehyde	18	24.3600	.04935	.01163	24.3355	24.3845	24.24	24.46
microwave	18	24.0907	.09216	.02172	24.0449	24.1365	23.93	24.21
Total	**54**	**24.2714**	**.14555**	**.01981**	**24.2316**	**24.3111**	**23.93**	**24.46**

Table 3: ANOVA results for post - treatment groups mean distances.

post_treatment_mean_distance					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	**.881**	**2**	**.441**	**92.924**	**<.001**
Within Groups	.242	51	.005		
Total	**1.123**	**53**			

Table 4: Tukey's test for multiple comparisons of post - treatment mean distances between disinfectant groups.

Dependent Variable: post_treatment_mean_distance						
					95% Confidence Interval	
(I) Groups	**(J) Groups**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**Lower Bound**	**Upper Bound**
Didecyldimethylammoium chloride	Gluteraldehyde	.00333	.02295	.988	-.0521	.0587
	Microwave	.27262*	.02295	<.001	.2172	. 3280
Gluteraldehyde	Didecyldimethylammonium chloride	-.00333	.02295	.988	-.0587	.0521
	Microwave	.26928*	.02295	<.001	.2139	.3247
Microwave	Didecyldimethylammonium chloride	-.27262*	.02295	<.001	-.3280	-.2172
	Gluteraldehyde	-.26928*	.02295	<.001	-.3247	-.2139

*The mean difference is significant at the 0.05 level

between the three groups' mean values as shown in table 2 and table 3. To find out which two groups have significant difference TUKEY'S TEST was conducted as shown in table 4.

Interpretation of paired-sample T test, since the p value >0.05, i-e 0.552 for group1, and 0.412 for group 2 , indicating no significant change in the dimensional accuracy of pre and post disinfectant treated groups. However, the 3rd group having p value <0.05 i-e <0.001, shows significant difference in dimensional accuracy as shown in table 5 and table 6.

The comparison between the Didecyldimethylammonium chloride treated group and glutaraldehyde treated group showed a mean difference of .00333, which is not statistically significant (p = .988).

Table 1: Grading results of surface detail reproduction after disinfection treatment

Groups	Grades	Surface detail reproduction
3 % Didecyldimethylammonium chloride	Grade 1	100%
2 % Glutaraldehyde	Grade 1	100%
Microwave Disinfection	Grade 1	100%

However, when comparing Didecyldimethylammonium chloride treated group and microwave disinfected group, a statistically significant mean difference of .27262 (p < .001) was found.

Similarly, comparing the glutaraldehyde treated group and microwave disinfected group , statistically significant mean difference of .26928 (p < .001) was obtained.

These results reveal that the differences in the mean distances between the groups treated with Didecyldimethylammonium chloride or glutaraldehyde and the group treated with microwave are statistically significant. However, the difference between the groups treated with Didecyldimethylammonium chloride and glutaraldehyde was found not to be statistically significant.

In the Didecyldimethylammonium chloride group, the pair's mean difference is positive, indicating that the mean score of pre-treatment group 1 is slightly higher than the mean score of post-treatment group 1, which indicates slight contraction in the dimensions of impression, after the treatment with disinfectant. However, the p-value indicates that the difference observed is not statistically significant at the p value of 0.05.

Table 5: Paired samples T-test for Pre- and Post treatment mean distances.

Paired Samples Test Paired Differences									Sig. (2-tailed)
					95% Confidence Interval of the Difference				
	Groups	**Mean**	**Std. Deviation**	**Std. Error Mean**	**Lower**	**Upper**	**t**	**df**	
Pair 1	Pre treatment group 1 - Post treatment group 1	.01100	.07687	.01812	-.02723	.04923	.607	17	.552
Pair 2	Pre treatment group 2 - Post treatment group 2	-.01753	.08846	.02085	-.06152	.02646	-.841	17	.412
Pair 3	Pre treatment group 3 - Post treatment group 3	.29206	.10638	.02507	.23916	.34496	11.648	17	<.000

Table 6: Paired samples statistics for pre- and post- treatment mean distances across different groups.

Paired Samples Statistics					
	Groups	**Mean**	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Pre treatment group 1	24.3743	18	.03776	.00890
	Post treatment group 1	24.3633	18	.05739	.01353
Pair 2	Pre treatment group 2	24.3425	18	.05956	.01404
	Post treatment group 2	24.3600	18	.04935	.01163
Pair 3	Pre treatment group 3	24.3828	18	.05486	.01293
	Post treatment group 3	24.0907	18	.09216	.02172

In the glutaraldehyde group, the pair's mean difference is negative, indicating that the group 2 pre-treatment mean score is slightly lower than the group 2 post-treatment mean score which indicates slight expansion in the dimensions of impression. However this difference, like in Pair 1, is not significant statistically based on the p-value.

In microwave disinfection group, the mean difference is positive and relatively large, indicating that the group 3 pre-treatment mean score is significantly higher than the group 3 post-treatment mean score, which indicates that there is contraction in the dimensions of impression. The p-values, both one-sided and two-sided, are highly significant ($p < 0.001$), indicating strong evidence of a significant difference between the groups.

DISCUSSION

Dental impressions and the resultant dental casts play a crucial role in fabricating accurate dental prostheses and restorations[1,2]. To ensure the success of dental treatments, precise surface detail reproduction and dimensional accuracy of gypsum casts obtained from impressions are two important requirements[27,30]. The aim of this study was to investigate the impact of different disinfection procedures on the dimensional accuracy and surface detail reproduction of gypsum casts retrieved from vinyl siloxane ether (VSE) impressions.

Due to the high risk of cross-infection, prevention and control of disease transmission is of prime importance in dental practice. Chemical disinfection, microwave irradiation, sterilization and cast disinfection are some of the infection control practices suggested by the American Dental Association (ADA) and the Centers for Disease Control and Prevention (CDC) for disinfection of dental impressions[24,31]. However, the impact of some of these practices on the properties of impression materials, particularly VSE, has not been investigated thoroughly.

The findings of this study indicate that 3% Didecyldimethylammonium chloride (DDAC), 2% glutaraldehyde, and microwave disinfection all resulted in satisfactory surface detail reproduction, as per ADA specifications. These disinfection methods effectively eliminated potentially harmful pathogens from the impressions without compromising surface detail reproduction. These outcomes align with the findings reported in a previous investigation, in which majority of the casts retrieved from addition-cured silicone impression material and condensation-cured silicone impressions exhibited excellent surface quality subsequent to the disinfection process, in contrast to casts produced from alginate and zinc oxide-eugenol impressions after disinfection[5].

Comparable results were observed in another research, where it was found that the casts retrieved from polyether and addition silicon impressions, immersed in acidic glutaraldehyde, more accurately replicated the surface details of the reference standard compared to casts fabricated from polysulfide material[26]. Regarding dimensional stability, the results revealed dimensional accuracy of VSE impressions was not significantly affected by DDAC and glutaraldehyde disinfection. In our study, immersion disinfection with 2% glutaraldehyde solution for 10 minutes and 3% DDAC solution for 30 minutes of the impression samples was done, following ADA recommendations. ADA advises short-duration disinfection for polyether impressions with approved disinfectants, limiting immersion to 30 minutes to prevent potential expansion[30]. Many previous studies[3,33,28,5] demonstrated that all impressions created using vinyl siloxane impression material showed minimal dimensional change, in accordance with the clinically acceptable limit set by the ANSI/ADA standard. In contrast to these studies, Nassar et al's research revealed contraction in vinyl siloxane ether (VSE) compared to non-disinfected VSE after immersion in a 2.5% glutaraldehyde disinfection solution for two weeks[15]. However, our study differed in that the impression was not stored, and dimensional changes were immediately measured post-disinfection.

However, microwave disinfection led to a statistically significant contraction in the dimensions of VSE impressions. This contraction could be attributed to the thermal effects of microwave disinfection, which may have caused slight distortion or contraction of the impression material. Recent research has validated the efficacy of household microwave ovens in achieving complete sterilization of various items, including dentures, nasal hoods, contact lenses, dental casts, resins, and liners. This method offers simplicity, affordability, and effective disinfection[33]. Microwave heating converts energy internally and disrupts bacterial cell membranes, inhibiting their growth and metabolism, thereby proving to be an excellent disinfection method[34]. Findings of our study are comparable to the study[32],

which concluded that greatest dimensional changes were observed in case of microwave disinfection, followed by the autoclave method and chemical sterilization. This discrepancy could be attributed to the absorption of elastomer fluid in the microwave method and the inherent dryness of microwaves[32]. However a previous study[33] have demonstrated mild contraction in impression which was statistically insignificant, by utilizing 720 watts microwave radiation for 7 minutes. While, in our study, a microwave power of 650 watts was applied for 8 minutes. It is plausible that variations in wattage and duration may have contributed to different outcomes, potentially leading to greater dimensional changes.

It is noteworthy that no significant changes in dimensional accuracy in case of DDAC and glutaraldehyde disinfection were observed, hence the integrity of the impressions was maintained, indicating their compatibility with VSE material. On the other hand, the significant contraction observed with microwave disinfection raises concerns about its suitability for VSE impressions, especially in cases where dimensional accuracy is critical.

Further research could be carried out in the future, focusing on effects of alternative disinfection methods on the properties of dental casts retrieved from vinyl siloxane ether impression material.

CONCLUSION

No statistically significant impact was observed on dimensional accuracy and surface detail reproduction of gypsum casts retrieved from Vinyl siloxane ether impressions treated with Didecyldimethylammoium chloride 3% and Glutaraldehyde 2% immersion procedures while the microwave disinfection method shall be used with caution.

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