Original Article

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Dentistry Section

A Comparative Evaluation of Dimensional Accuracy and Surface Detail Reproduction for Polyvinyl Siloxane and Vinyl Siloxane Ether under Dry and Moist Conditions- An In-vitro Study

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ABSTRACT

Introduction: The conventional impression procedure plays a major role in prosthodontics inspite of advancement in intra-oral scanning devices and 3D imaging procedures. Dimensional accuracy and surface detail reproduction are important for recording an impression.

Aim: The study evaluated and compared the dimensional accuracy and surface detail reproduction of Polyvinyl Siloxane (PVS) and vinyl siloxane ether impression materials when used under dry and moist conditions.

Materials and Methods: An in-vitro study was conducted in the Department of Prosthodontics, Rural Dental College, Pravara Institute of Medical Sciences, Loni, Ahmednagar, Maharashtra, India, for a period of two years from October 2018 to September 2020. A total of 60 impressions were made with PVS (Group A) and vinyl siloxane ether (Group B) under dry (A1, B1) and moist (A2, B2) conditions of stainless steel dies which had lines engraved on superior surface of the die. Using a Harloc's Tool maker's microscope, dimensional accuracy was measured by comparing the width of line Y in each impression. Surface detail reproduction was evaluated by American Dental Association (ADA) specification no. 19 where it stated continuous replication of at least any two lines out of the three lines inscribed on the die. Data analysis processing was performed in the SYSTAT version 12 (made by Crane's software, Bangalore). Student's unpaired t-test and Chi-square test were performed to determine statistical difference between PVS and vinyl siloxane ether where the level of significance was set at 5% and 1%.

Results: The mean dimensional change and SD values for PVS under dry condition ranged from 21.93±2.46 to 22.40±2.89 (in mm). The mean dimensional change and SD values for PVS under moist condition ranged from 22.87±3.20 to 23.33±3.42. The mean dimensional change and SD values for vinyl siloxane ether under dry condition ranged from 21.93±3.61 to 24.73±5.20. The mean dimensional change and SD values for vinyl siloxane ether under moist condition ranged from 21.93±4.48 to 22.87±4.15. No statistical difference was found under dry and moist conditions within 2 hours and after 24 hours for both the materials.

Conclusion: The study revealed no significant difference between dimensional accuracy and surface detail reproduction for PVS and vinyl siloxane ether. Both the materials can reproduce the details under dry and moist conditions satisfactorily and remained dimensionally stable till 24 hours after impression making.

Keywords: Addition silicone, Elastomers, Hydrophilic, Impression, Moisture, Saliva

INTRODUCTION

Successful outcome of a fixed dental prosthesis is influenced by a cascade of multiple steps such as diagnosis, treatment planning, tooth preparation, impression making, temporisation and lab procedure. Impression making is one of the crucial steps in fabricating a well fitting prosthetic restoration. Conventional impression process still has a role in conveying information of the patient to the dental laboratory. The accuracy of the impression can be influenced by various factors namely periodontal status, oral hygiene, saliva, location of the prepared finish lines [1]. Moisture from saliva may interfere while recording impressions and may also affect dimensional accuracy and surface detail reproduction at impression margins. Impression technique, impression tray, and properties of the impression material are some of the other factors that influence the precision of an impression.

Hence, dimensional accuracy and surface detail reproduction are few of the essential prerequisite that are considered important for recording an accurate impression [2].

The four kinds of elastomers which are used as impression materials are polysulfide, condensation silicone, addition silicone and polyether. According to American Dental Association (ADA) specification no. 19, the ability of an impression material to maintain the accuracy of the impression over time is measured by dimensional stability. Elastomeric impression materials are capable of reproducing fine details of 25 microns or less. Hydrophilicity, polymerisation shrinkage, byproduct evaporation from polymerisation reactions, shrinkage from thermal modification, incomplete elastic recovery, and time elapsed for impression pouring can all cause dimensional changes in elastomeric impression materials [3].

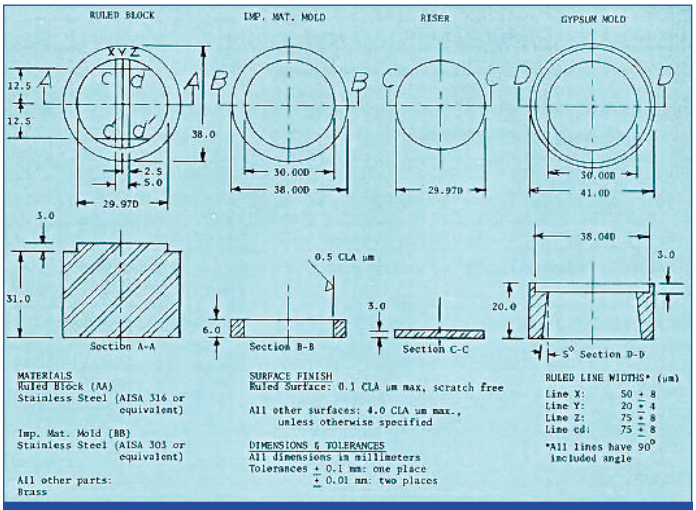
A hydrophilic product namely polyether has better mechanical properties, good elastic recovery, and less amount of shrinkage that makes it superior to hydrocolloids and condensation type materials. On the other hand, Polyvinyl Siloxane (PVS) (also called as addition silicone) material includes excellent elastic recovery, ease of handling, ability to reproduce multiple casts from single impression, and good surface detail reproducibility [4]. An addition reaction occurs between the silane and vinyl groups during mixing of PVS causing minimal dimensional change during polymerisation with no by-products [5].

A new material known as vinyl siloxane ether was introduced in the year 2009 which boasts of instant hydrophilicity while also combining the best features of both polyether and PVS [6]. Although the exact composition is proprietary, the vinyl siloxane ether manufacturer data sheet shows that Polyether constitutes 5% to 20% of the total composition to increase the material's hydrophilicity, thus making a final impression more successful where humidity is a concern [7]. The manufacturers claim that this new impression material has good mechanical and flow properties with outstanding dimensional stability even when the impression is unpoured for up to two weeks [8]. Hence, the current study aimed to evaluate and compare the dimensional accuracy and surface detail reproduction of PVS and vinyl siloxane ether impression material when used under dry and moist conditions.

MATERIALS AND METHODS

An in-vitro study was conducted in the Department of Prosthodontics, Rural Dental College, Pravara Institute of Medical Sciences, Loni, Ahmednagar, Maharashtra, India, for a period of two years from October 2018 to September 2020. Clearance from the Institutional Ethical Committee was obtained (no. PIMS/RDC/IEC/UG-PG/21-20180. As described in American National Standards Institute (ANSI)/ American Dental Association (ADA)/ADA specification no. 19 [Table/Fig-1] [9], a total of 60 impressions were made with PVS (Group A) and vinyl siloxane ether (Group B) under dry (A1, B1) and moist (A2, B2) conditions of stainless steel dies which had lines engraved on superior surface of the die. Using a Holmarc's Tool maker's microscope (Mitutoyo 176-901-1A) (accuracy of 0.001 mm) dimensional accuracy was measured by comparing the width of line Y (0.02 mm) in each impression. Surface detail reproduction was evaluated by using criteria similar to ADA specification no. 19 where it stated continuous replication of at least any two lines out of the three lines inscribed on the die. If at least two of the three horizontal lines were reproduced continuously, the impression was considered satisfactory. All the other impressions were rated unsatisfactory [Table/Fig-2] [10].

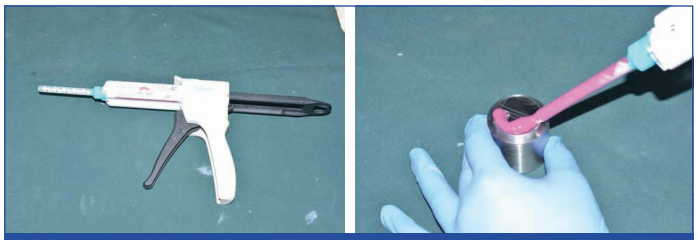
Impression material was injected onto the surface of die, using dispensing tips and pentamix machine (3M ESPE) [Table/Fig-3] for vinyl siloxane ether (Kettenbach Identium) and an auto-mixing gun (Dentsply) [Table/Fig-4] for PVS (Aquasil- Dentsply Sirona).



[Table/Fig-1]: ADA specification no. 19 for die [9].

[Table/Fig-2]: Die fabrication (according to ADA specification no. 19).
[Table/Fig-3]: Pentamix machine. (Images from left to right)

Dry condition: Impressions were made under dry condition by injecting the material onto the die surface [Table/Fig-5,6] and the mold was placed onto the die which acted as a tray to enclose the material and to ensure a uniform thickness of the impression material. Impression material was placed on the ruled block and to extrude the excess material a rigid, flat, riser was pressed over this impression [Table/Fig-7]. To standardise the pressure on the impression material during setting a weight of 300 gm was placed on top of the riser. After the setting of the material, the impression was retrieved from the die and the markings of the die were transferred on to the impression.

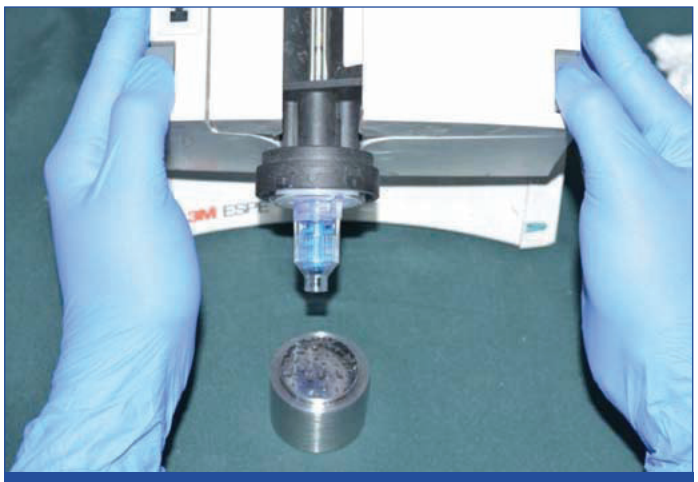


[Table/Fig-4]: Auto mixing gun (Dentsply). **[Table/Fig-5]:** Impression procedure for Polyvinyl Siloxane (PVS) under dry condition. (Images from left to right)

[Table/Fig-6]: Impression procedure for vinyl siloxane ether under dry condition.
[Table/Fig-7]: Extrusion of excess material. (Images from left to right)

Moist condition: A fine mist of water from a spray bottle was applied to the surface of the die before the impression material was syringed onto the die surface avoiding any excess of water under moist condition [Table/Fig-8-10]. The same procedure as described above was followed to obtain the impression [11].

[Table/Fig-8]: A fine mist of water sprayed on the die to make impression under moist condition. **[Table/Fig-9]:** Impression procedure for Polyvinyl Siloxane (PVS) under moist condition. (Images from left to right)



[Table/Fig-10]: Impression procedure for vinyl siloxane ether under moist condition.

Dimensional Accuracy (in mm) were measured under dry (A1, B1) and moist (A2, B2) conditions within 2 hours and after 24 hours of impression making. Surface detail reproduction of metal die with both impression materials under dry and moist conditions were also recorded.

STATISTICAL ANALYSIS

Data were entered as mean and standard deviation. Data analysis processing was performed in the SYSTAT version 12 (made by Crane's software, Bangalore). unpaired t-test and Chi-square test were performed to determine statistical difference between PVS and vinyl siloxane ether where the level of significance was set at 5% and 1%, respectively. Null hypothesis stated that there will be no significant difference in dimensional accuracy and surface detail reproduction of the impression materials under dry and moist conditions.

RESULTS

Dimensional accuracy showed no statistically significant difference under dry and moist conditions within 2 hours and after 24 hours for PVS and vinyl siloxane ether as mentioned in [Table/Fig-11,12].

Time period	Dimensional accuracy (mm)			
	Dry condition A_1 (n=15) Mean±SD	Dry condition B_1 (n=15) Mean±SD	Student's Unpaired t-test value	p-value
Within 2 hours of impression making	21.93±2.46	21.93±3.61	0.00	p>0.05
After 24 hours of impression making	22.40±2.89	24.73±5.20	1.5169	p=0.089

[Table/Fig-11]: Comparison of mean and SD values of dimensional accuracy (mm) under dry condition (A1 and B1) within 2 hours and after 24 hours of impression making in Group A (Polyvinyl Siloxane) and in Group B (Vinyl Siloxane Ether).
p-value <0.05* statistically significant

Time period	Dimensional accuracy (mm)			
	Moist condition A_2 (n=15) Mean±SD	Moist condition B_2 (n=15) Mean±SD	Student's Unpaired t-test value	p-value
Within 2 hours of impression making	22.87±3.20	21.93±4.48	0.6619	p=0.2489
After 24 hours of impression making	23.33±3.42	22.87±4.15	0.4295	p=0.2133

[Table/Fig-12]: Comparison of mean and SD values of dimensional accuracy (mm) under moist conditions (A2 and B2) within 2 hours and after 24 hours of impression making in Group A (Polyvinyl Siloxane) and in Group B (Vinyl Siloxane Ether).
unpaired' test
p-value <0.05* statistically significant

By applying student's unpaired t-test there was no significant difference dimensional accuracy (in mm) for PVS and vinyl siloxane ether under dry condition within 2 hours and after 24 hours of impression making as seen in [Table/Fig-11].

The dimensional accuracy for PVS under moist condition within 2 hours was 22.87±3.20 mm which was slightly higher than vinyl siloxane ether which showed mean dimensional accuracy as 21.93±4.48 mm. However, the difference was not statistically significant (p-value >0.05).

By applying chi-square test there was no significant association between surface detail reproduction of metal die under dry condition and moist condition in Group A (A1 and A2). Surface detail reproduction for PVS under dry condition was 60% satisfactory and 86.67% satisfactory under moist condition of the total sample size. Surface detail reproduction of PVS and vinyl siloxane ether under dry and moist conditions were satisfactory. The PVS could perform better under moist conditions as mentioned in [Table/Fig-13] whereas vinyl siloxane ether could perform better under dry conditions [Table/Fig-14] as they could reproduce maximum lines out of the three lines inscribed on the die. By applying Chi-square test there was no significant association between surface detail reproduction of metal die under dry and moist conditions in Group B (B1 and B2). Surface detail reproduction for vinyl siloxane ether under dry condition was 80% satisfactory whereas under moist condition it was 60% satisfactory of the total sample size (According to ADA specification no. 19, continuous replication of at least any two lines out of the three lines).

Surface detail reproduction	Dry condition A_1 (n=15)	Moist condition A_2 (n=15)
Satisfactory	9 (60%)	13 (86.67%)
Unsatisfactory	6 (40%)	2 (13.33%)

[Table/Fig-13]: Evaluation of surface detail reproduction of metal die with Polyvinyl Siloxane (PVS) impression material under dry and moist conditions using Chi-square test.
Value of χ^2=1.534, p=0.2155, not significant

Surface detail reproduction [9]	Dry condition B_1 (n=15)	Moist condition B_2 (n=15)
Satisfactory	12 (80%)	9 (60%)
Unsatisfactory	3 (20%)	6 (40%)

[Table/Fig-14]: Evaluation of surface detail reproduction of metal die with vinyl siloxane ether impression material under dry and moist conditions using chi-square test.
Value of χ^2=0.6349, p=0.4256, not significant

DISCUSSION

Despite tremendous progress in the field of impression materials and procedures there is little evidence that supports the claim newly formulated vinyl siloxane ether to be inferior to other silicone impression materials despite its good mechanical and flow properties with outstanding dimensional stability even when the impression is unpoured for up to two weeks [12]. There are various factors that affect the accuracy of the impression such as selection of impression material, impression technique, mixing and loading the material into an adhesive coated tray and placing in the patient's mouth, degree of distortion on removal from mouth, storage of the set impression, duration of storage prior to the preparation of a model or die. Also, thermal contraction on cooling from mouth to room temperature and dimensional changes during setting is factors that have some effect on accuracy [13]. In this laboratory study an attempt was made to reduce the variables associated with fluid composition, thus the ability of the impression material to reproduce surface detail was assessed in the presence or absence of water.

Many factors are important in choosing a material for making impressions. Some of the factors involved are accuracy, elastic recovery, dimensional stability, long shelf-life and patient comfort [14]. A study by Quazi MA et al., claimed that impression materials have reached to the point that accuracy can be managed more by technique than by the material itself [15] while Caputi S and Varvara G indicated that impression technique does not affect the dimensional accuracy of impressions [16]. The various methods used to determine the accuracy of the impression include [17]:

1. Linear measurements are used to determine the material's properties.
2. Tests involving the creation and calculation of gypsum dies from impression material, where these dies are dimensionally measured.
3. Methods which employ the use of master dies and casting

In the present study, linear test which measures the material was used which included a stainless steel die prepared according to ADA specification no. 19 which had the linear patterns inscribed on it [9]. One of the properties which influences the accuracy of elastomeric impression material is hydrophobicity. It can be described by the material's chemical structure, which contains hydrophobic, aliphatic hydrocarbon groups surrounding the siloxane bond. Since their chemical structure include accessible functional groups that attract and associate with water molecules by hydrogen bonding, polyether and polysulphide impression materials are more hydrophilic than PVS [4].

Hydrophobic nature of the PVS impression materials can be explained by two attributes. The first attribute defines the surface energy of the solid, polymerised PVS and the second attribute refers to the surface energy of the unpolymerised liquid phase of the impression material and the lack of its ability to wet oral tissues during impression making. Intrinsic surfactants (nonylphenoxy polyethanol homologues) have been incorporated by the manufacturers to overcome drawback of hydrophobicity and these materials are marketed as hydrophilic PVS impression materials. Hydrophilic PVS impression materials when used clinically in presence of moisture have proven to increase wettability of the polymerised impressions yet these materials reported a decrease in accuracy of the impressions.

Inaccuracies in the presence of moisture mean that hydrophilic additives cannot increase the ability of unpolymerised PVS to wet the oral tissues under moisture conditions, affecting the overall accuracy and detail reproduction of the impression.

This necessitates the evaluation of these two parameters under dry and moist conditions [18].

In the present study, the width of the line Y were measured on the impressions at the time intervals of 2 hours and 24 hours. The elastomeric impression materials have maximum polymerisation shrinkage for the initial 1 hour after making of the impression. During the 24 hours following removal of the impression from the mouth the rate of shrinkage of elastomeric impression materials is not uniform In general, about half the shrinkage observed at 24 hours occurs within the first hour after removal [19]. Also, according to ADA specification no.19, negative change in dimension is 0.50% at 24 hours [9].

In most of the studies reported in literature so far, precision measurement was done using instruments such as universal length measuring machine [4], measuring microscope [20], vernier caliper and laser probes [17].

The results obtained from statistical tests showed non significant difference between dimensional accuracy (mm) in group PVS and group vinyl siloxane ether under dry as well as moist conditions within 2 hours and after 24 hours of impression making. These results are in accordance with the study conducted by Sirisha G et al., where difference in dimensional accuracy and surface detail reproduction amongst PVS, vinyl siloxane ether and polyether were found to be statistically non significant [21]. Similarly a study by Afshari Z et al., assessed the dimensional accuracy of vinyl siloxane ether, additional silicone and condensation silicone and found that vinyl siloxane ether had the greatest dimensional accuracy with no significant difference [22].

According to Petrie CS et al., no statistically significant interactive effect was found among conditions (dry, moist, or wet) for heavy-bodied, type I VPS (Aquasil) and the medium-bodied, type I VPS (Reprosil). In this study, the authors stated that non significant findings in the study can be attributed to several factors such as laboratory testing which does not mimic clinical situations. Calibrated surfaces on the metal dies do not resemble the behavior of oral tissue for precise comparison because metal dies do not absorb liquids. In addition, a metal dies intrinsic surface-free energy is much greater than that of surface-free energy of the prepared teeth and oral soft tissues [20]. Therefore, these findings should be substantiated by in vivo studies.

On the contrary a study by Mohammed DH et al., found significant difference between the three elastomeric impression materials for dimensional accuracy [23], Also, Petrie CS et al., found significant difference (p-value <0.05) between two elastomeric impression materials for dimensional accuracy under three different conditions [20].

The results of Chi-square test revealed no significant difference in surface detail reproduction for Group A (PVS) and Group B (vinyl siloxane ether) under dry and moist conditions. Also, study done by Petrie CS et al., suggested that moisture has significant effect on detail reproduction of elastomeric impression materials [20]. Therefore, it can be concluded that satisfactory impressions were higher than unsatisfactory in both the groups under dry and moist conditions. The null hypothesis of this study which stated that there is no difference in dimensional accuracy and surface detail reproduction were tested and accepted.

Further there is need to examine the biological, rheological and wetting properties of this new material, to further ascertain equivalence with the other elastomers.

Limitation(s)

The surface energy of metal die is different than that of prepared teeth and oral soft tissues. Hence, further clinical evaluation needs to be undertaken to substantiate study findings.

CONCLUSION(S)

Dimensional changes observed in both the materials i.e., vinyl siloxane ether and PVS were will within the requirements as per ADA specification no.19. Also, surface detail reproduction for PVS and vinyl siloxane ether reproduced satisfactory findings under dry and moist conditions.

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