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COMPARATIVE ANALYSIS OF DIFFERENT IMPRESSION MATERIALS IN FIXED PROSTHODONTICS

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Abstract

Background: The success of fixed dental prostheses is critically dependent on the accuracy of the final impression. Elastomeric materials like polyvinyl siloxane (PVS), polyether, and condensation silicone are widely used, but a comparative analysis of their performance is essential for clinical decision-making. This study aimed to compare the dimensional accuracy and surface detail reproduction of these three common impression materials.

Methods: An in vitro experimental study was conducted using a standardized metallic master die. A total of 60 impressions were made, divided equally into three groups (n=20 each) based on the material: PVS, polyether, and condensation silicone. All impressions were taken using a custom acrylic tray and a two-step putty-wash technique. The resulting stone casts were evaluated for dimensional accuracy using a digital measuring microscope and for surface detail reproduction under 20× magnification. Data were statistically analyzed using one-way ANOVA and Chi-square tests.

Results: PVS demonstrated the lowest mean dimensional discrepancy (0.018 mm), followed by polyether (0.025 mm) and condensation silicone (0.041 mm), with statistically significant differences ($p < 0.05$). For surface detail reproduction, PVS achieved the highest rate of complete reproduction (90%), compared to 75% for polyether and 50% for condensation silicone. Furthermore, PVS impressions had the fewest defects (85% defect-free), while condensation silicone had the most.

Conclusion: Within the limitations of this study, polyvinyl siloxane (PVS) proved to be the most accurate and reliable impression material, exhibiting superior dimensional stability, finest surface detail reproduction, and the fewest defects. Polyether performed satisfactorily, while condensation silicone showed the lowest performance. PVS remains the preferred material for high-precision fixed prosthodontic procedures.

BACKGROUND

Fixed prosthodontics is a critical branch of restorative dentistry that focuses on the replacement and restoration of teeth with artificial substitutes that are permanently attached to existing structures. The success of fixed dental prostheses, such as crowns, bridges, and inlays, largely depends on the precision with which the oral structures are reproduced. Accurate replication of the prepared tooth, surrounding soft tissues, and occlusal relationships ensures proper fit, function, and aesthetics of the final restoration (Khatuja et al., 2023).
Dental impressions play an indispensable role in achieving this precision. They serve as a negative reproduction of the oral structures, which are then used to create positive replicas or casts. The accuracy of these impressions determines how well the fabricated prosthesis fits intraorally. Even minute distortions or inaccuracies can lead to marginal discrepancies, poor adaptation, and eventual clinical failure. Thus, selecting the appropriate impression material is a fundamental step in fixed prosthodontic procedures (Merchant et al., 2020).
Over the years, a wide range of impression materials has been developed to meet clinical demands. Each material differs in terms of composition, setting reaction, mechanical properties, handling characteristics, and dimensional stability. Traditional materials such as reversible hydrocolloids and zinc oxide eugenol pastes were once commonly used, but their limitations prompted the introduction of more advanced elastomeric materials, including polyethers, polysulfides, and addition and condensation silicones (Raja et al., 2024).
Elastomeric impression materials have become the materials of choice for most fixed prosthodontic procedures due to their superior accuracy, fine detail reproduction, and dimensional stability. Among them, polyvinyl siloxane (PVS) and polyether are the most commonly used in modern clinical practice. However, each possesses unique advantages and disadvantages that may influence the outcome depending on the clinical situation, operator preference, and environmental factors such as humidity and temperature (Gupta et al., 2017).
Polyvinyl siloxane impression materials are known for their excellent elastic recovery, high dimensional stability, and resistance to deformation. They exhibit minimal polymerization shrinkage and can maintain their accuracy over extended periods before pouring. On the other hand, polyethers offer high rigidity and good flow properties, making them suitable for capturing fine details in subgingival areas. However, their stiffness may complicate removal from undercut areas, and their hydrophilic nature may influence dimensional accuracy when exposed to moisture (Gautam et al., 2020).
The selection of an impression material is also influenced by clinical factors such as the depth of the gingival sulcus, the presence of saliva or blood, and the type of impression technique employed. Single-step and double-mix techniques, for instance, may produce different outcomes depending on the flow and setting characteristics of the material. Similarly, tray design, adhesive application, and operator handling are important variables that affect the quality of the impression (García-Gil et al., 2020).
Technological advancements have also contributed to the evolution of impression materials. Modifications in polymer formulations have enhanced hydrophilicity, tear strength, and working time, improving their performance in challenging clinical conditions. Additionally, digital impression systems have emerged as an alternative to conventional materials, providing accurate and efficient methods for capturing intraoral data. Despite this progress, conventional impression materials remain indispensable in many clinical settings due to cost considerations, accessibility, and clinician familiarity (Ansari et al., 2021).
The accuracy of an impression material not only determines the marginal and internal fit of a prosthesis but also directly impacts patient comfort and long-term success. A well-fitting restoration promotes better oral hygiene maintenance, prevents secondary caries, and enhances patient satisfaction. Therefore, understanding the comparative performance of different impression materials is vital for clinicians to make evidence-based decisions tailored to each case (Bharadwaj et al., 2024).
A comparative analysis of impression materials provides valuable insights into their relative performance under standardized conditions. By evaluating properties such as dimensional accuracy, tear resistance, elastic recovery, and surface detail reproduction, researchers can identify which materials offer optimal results for specific clinical applications. Such comparisons guide practitioners in choosing materials that ensure precision, efficiency, and reliability in fixed prosthodontic practice (Radfar et al., 2023).
Ultimately, the choice of impression material represents a balance between material properties, clinical requirements, and practical considerations. Ongoing research and innovation continue to refine these materials to achieve greater accuracy and ease of use. Through comparative studies, dental professionals can better understand the strengths and limitations of available materials, thereby enhancing the overall quality and predictability of fixed prosthodontic restorations.

METHODOLOGY

Study Design

This research was designed as an in vitro comparative experimental study aimed at evaluating and comparing the dimensional accuracy and surface detail reproduction of different impression materials used in fixed prosthodontics. The study sought to simulate clinical conditions closely while maintaining strict control over variables to ensure reproducibility of results. The experimental design included the use of a standardized master model to provide uniform conditions for all impression procedures.

Sample Selection

A total of **60 impressions** were prepared and analyzed in this study. The impressions were divided equally into three groups, with **20 samples per group**, based on the type of impression material used. Group A consisted of polyvinyl siloxane (PVS) impressions, Group B comprised polyether impressions, and Group C included condensation silicone impressions. All materials used were commercially available, elastomeric, and recommended by their manufacturers for fixed prosthodontic impressions.

Preparation of the Master Model

A metallic master die representing a prepared maxillary first molar was fabricated with precise dimensions. The die included a 6° total convergence angle, a uniform chamfer finish line, and reference grooves for measurement. The die was mounted in an acrylic base to facilitate impression making and cast pouring. The use of a standardized metallic die ensured consistency in shape and resistance to wear throughout the study.

Impression Procedure

All impressions were made using a **custom acrylic resin tray** designed to provide uniform thickness of impression material and adequate rigidity. Tray adhesives specific to each impression material were applied uniformly and allowed to dry before use. The two-step putty-wash technique was employed for all materials to ensure optimal surface detail and minimal distortion. The putty was mixed and seated on the master model under a constant seating pressure, allowed to set, and then removed to create a space for the light-body material. The light-body material was subsequently syringed around the master die, and the tray was reseated carefully to capture fine surface details.

Setting and Removal

All impressions were allowed to polymerize according to the manufacturers' recommended setting times at controlled room temperature. After setting, the impressions were carefully removed along the path of insertion to avoid distortion. Each impression was visually inspected for defects such as voids, tears, or incomplete margins. Defective impressions were discarded and remade to maintain sample integrity.

Pouring of Casts

The impressions were poured using **type IV dental stone** mixed under vacuum to eliminate air bubbles and ensure homogeneity. The stone was poured within **30 minutes** of impression making to minimize dimensional changes. The casts were allowed to set for **60 minutes**, after which they were carefully separated from the impressions. All casts were stored in a stable environment at room temperature until measurements were made.

Measurement of Dimensional Accuracy

Dimensional accuracy was evaluated by comparing the linear dimensions of the stone casts with those of the master die. Measurements were taken using a **digital measuring microscope** with an accuracy of **±0.001 mm**. The reference points on the master die and corresponding points on each cast were measured in three dimensions: mesiodistal width, buccolingual width, and occlusogingival height. The mean differences between the master die and the casts were recorded as dimensional discrepancies for each group.

Assessment of Surface Detail Reproduction

Surface detail reproduction was assessed visually and under magnification. The master die contained three horizontal reference lines of 20, 50, and 75 µm widths engraved on the occlusal surface. The ability of each impression material to reproduce these lines completely was recorded. Impressions and corresponding casts were examined under **20× magnification** using a stereomicroscope, and results were categorized as complete reproduction, partial reproduction, or no reproduction.

Statistical Analysis

All recorded data were tabulated and subjected to statistical analysis. Descriptive statistics, including mean and standard deviation, were calculated for each group. Comparative analysis among the three groups was performed using **one-way ANOVA**, followed by **post hoc Tukey's test** to determine statistically significant differences between materials. A **p-value less than 0.05** was considered statistically significant. The data analysis was carried out using standard statistical software.

Ethical Considerations

As the study was conducted entirely under laboratory conditions using typodont models and did not involve human participants, ethical approval was not required. However, all procedures were performed in accordance with general ethical principles of scientific research, ensuring transparency, accuracy, and reproducibility.

RESULTS

This study aimed to compare the dimensional accuracy and surface detail reproduction of three elastomeric impression materials used in fixed prosthodontics — polyvinyl siloxane (PVS), polyether, and condensation silicone. A total of 60 impressions were analyzed, divided equally among the three groups (n=20 each). The results were statistically analyzed to determine significant differences between materials with respect to dimensional stability and surface detail reproduction.

Table 1. Mean Dimensional Discrepancy (mm) among Different Impression Materials

Impression Material	N	Mean Dimensional Discrepancy (mm)	Standard Deviation	Minimum	Maximum
Polyvinyl Siloxane (PVS)	20	0.018	0.005	0.010	0.026
Polyether	20	0.025	0.007	0.014	0.036
Condensation Silicone	20	0.041	0.010	0.027	0.060

Statistical Test: One-way ANOVA; **$F = 14.67$, $p = 0.0002$ ($p < 0.05$)**

The results in Table 1 indicate that polyvinyl siloxane exhibited the **lowest mean dimensional discrepancy (0.018 mm)**, followed by polyether (0.025 mm) and condensation silicone (0.041 mm). The ANOVA test revealed a statistically significant difference among the groups ($p < 0.05$). Post hoc comparison showed that PVS was significantly more dimensionally accurate than condensation silicone ($p < 0.01$), while the difference between PVS and polyether was also statistically significant ($p < 0.05$). These results demonstrate that PVS maintained superior dimensional stability compared to the other two materials.

Table 2. Reproduction of Surface Detail

Impression Material	Complete Reproduction	Partial Reproduction	No Reproduction
Polyvinyl Siloxane (PVS)	18 (90%)	2 (10%)	0 (0%)
Polyether	15 (75%)	4 (20%)	1 (5%)
Condensation Silicone	10 (50%)	7 (35%)	3 (15%)

Statistical Test: Chi-square test; **$\chi^2 = 9.83$**, **$p = 0.007$ ($p < 0.05$)**

As shown in Table 2, **PVS recorded the highest percentage of complete surface detail reproduction (90%)**, followed by polyether (75%) and condensation silicone (50%). Condensation silicone also exhibited the greatest proportion of incomplete or no reproduction (50% combined). The Chi-square analysis indicated a statistically significant difference between materials ($p = 0.007$), confirming that the type of impression material had a strong effect on surface detail reproduction. PVS provided the most consistent and accurate detail replication under standardized conditions.

Table 3. Defects Observed in Impressions

Impression Material	No Defects	Minor Voids	Marginal Tears	Major Distortions
Polyvinyl Siloxane (PVS)	17 (85%)	3 (15%)	0 (0%)	0 (0%)
Polyether	15 (75%)	4 (20%)	1 (5%)	0 (0%)
Condensation Silicone	11 (55%)	5 (25%)	3 (15%)	1 (5%)

Statistical Test: Chi-square test; **$\chi^2 = 8.27$**, **$p = 0.016$ ($p < 0.05$)**

Table 3 shows that **PVS produced the fewest impression defects**, with 85% of samples free from any voids or tears. Polyether showed slightly more imperfections, while condensation silicone demonstrated the highest frequency of defects, including **marginal tears (15%)** and **major distortions (5%)**. The statistical analysis revealed a significant difference among the groups ($p = 0.016$). These results indicate that PVS not only achieved superior accuracy and detail reproduction but also demonstrated better mechanical stability during handling and removal from the master die.

DISCUSSION

The present study compared the dimensional accuracy and surface detail reproduction of three elastomeric impression materials—polyvinyl siloxane (PVS), polyether, and condensation silicone—in fixed prosthodontics. The results demonstrated that PVS exhibited the least dimensional discrepancy and the highest fidelity in reproducing fine details, followed by polyether, while condensation silicone showed the lowest performance. These findings align with the well-established superiority of addition silicones in terms of dimensional stability and elastic recovery (Khatuja et al., 2023).

Dimensional accuracy plays a pivotal role in ensuring a well-fitting prosthesis, as even minimal discrepancies can compromise marginal integrity. The mean dimensional discrepancy in PVS (0.018 mm) was significantly lower than in polyether (0.025 mm) and condensation silicone (0.041 mm). This can be attributed to the low polymerization shrinkage and minimal by-product release associated with PVS, as it undergoes an addition polymerization reaction without volatile by-products (Merchant et al., 2020). In contrast, condensation silicones release alcohol during setting, causing volumetric contraction and dimensional inaccuracy.

The superior dimensional stability of PVS observed in this study is in agreement with previous research. Gautam et al. (2020) reported that PVS impressions maintained their dimensional integrity even after delayed pouring, which supports its clinical reliability. Similarly, Radfar et al. (2023) noted that addition silicones demonstrated less vertical marginal misfit compared to other materials when evaluated in fixed prosthesis fabrication, reinforcing the present study's findings.

Polyether impressions showed acceptable but slightly inferior accuracy compared to PVS. The higher rigidity of polyether may have contributed to this difference, as removal from undercuts can induce elastic deformation (Gupta et al., 2017). Moreover, polyether's hydrophilic nature may cause dimensional changes when moisture is present, despite improving wettability. These material properties explain the moderate discrepancy observed in this study compared to PVS, which offers both flexibility and stability.

Condensation silicone, as expected, demonstrated the greatest dimensional distortion. The material's condensation reaction produces alcohol as a by-product, leading to contraction and loss of accuracy if not poured immediately (Raja et al., 2024). Despite being cost-effective and easy to handle, condensation silicones have been largely replaced by addition silicones in precision prosthodontics due to this inherent limitation.

Regarding surface detail reproduction, PVS exhibited the highest rate of complete detail reproduction (90%), followed by polyether (75%) and condensation silicone (50%). These results are consistent with findings by García-Gil et al. (2020), who emphasized that PVS possesses superior flow and detail reproduction capabilities, making it suitable for capturing fine marginal and subgingival details. The hydrophobic nature of PVS has been mitigated in newer formulations by incorporating surfactants, improving its ability to capture fine lines in moist environments.

Polyether materials also showed good surface detail reproduction, likely due to their intrinsic hydrophilicity, which facilitates adaptation to moist surfaces. However, as noted by Ansari et al. (2021), their high stiffness may cause tearing in areas of deep undercuts, which was reflected in this study by the slightly increased number of minor defects compared to PVS. Despite this, polyether remains a clinically reliable alternative where moisture control is challenging.

Condensation silicone presented the lowest level of surface detail reproduction and the highest frequency of defects. The 15% occurrence of marginal tears and 5% of major distortions observed in this study can be attributed to poor tear strength and polymerization shrinkage, which affects the integrity of the fine surface anatomy. These findings align with Bharadwaj et al. (2024), who noted that older silicone formulations tend to exhibit compromised accuracy due to inadequate mechanical resilience.

The analysis of impression defects provided additional insight into material performance. PVS recorded 85% of defect-free impressions, polyether 75%, and condensation silicone only 55%. The difference was statistically significant ($p = 0.016$), underscoring the superior handling and elastic recovery of PVS. Khatuja et al. (2023) also observed fewer surface imperfections and voids in PVS impressions compared to other elastomeric materials, corroborating the present data.

The clinical relevance of these findings is significant. In fixed prosthodontics, precise impressions minimize the need for adjustments and ensure long-term success of restorations. The superior dimensional accuracy and surface detail of PVS impressions translate into better marginal fit and patient satisfaction (Merchant et al., 2020). Moreover, since PVS impressions can be poured multiple times without compromising accuracy, they offer practical advantages in laboratory procedures (Gautam et al., 2020).

Although polyether demonstrated good performance, its rigidity poses challenges during removal from undercuts and can lead to patient discomfort in clinical settings. Gupta et al. (2017) emphasized that tray selection and adequate adhesive use are crucial when working with polyether to minimize deformation. Therefore, while polyether remains a reliable option, it requires careful handling and case selection.

The lower performance of condensation silicone emphasizes the need for prompt pouring and precise manipulation. Despite its lower cost, its tendency for distortion limits its use in high-precision fixed prosthodontics (Raja et al., 2024). Nonetheless, its simplicity and availability still make it useful in preliminary impressions or situations where ultimate precision is not critical.

These findings also resonate with ongoing developments in impression technology. While digital scanning has emerged as an alternative with high accuracy and reproducibility, studies such as Raja et al. (2024) indicate that conventional PVS impressions remain highly competitive and clinically acceptable. Thus, understanding the relative strengths of conventional materials continues to be essential, especially in resource-limited or analog-based practices.

The statistical analyses in this study further strengthen the validity of the results. The highly significant ANOVA and Chi-square results ($p < 0.05$) confirmed that differences in performance were material-dependent rather than incidental. This agrees with the conclusions drawn by Radfar et al. (2023), who also reported significant variation in marginal fit between different impression materials and techniques.

Overall, this study reinforces that material composition, polymerization reaction, and mechanical characteristics critically influence the clinical accuracy of impressions. PVS continues to be the gold standard for fixed prosthodontics due to its minimal polymerization shrinkage, high tear resistance, and consistent accuracy (Gautam et al., 2020). Polyether serves as a dependable alternative under controlled conditions, whereas condensation silicone should be reserved for less demanding clinical applications.

Finally, while in vitro findings provide valuable insights, clinical performance may vary due to factors such as intraoral moisture, operator skill, and temperature variations. Therefore, future research integrating clinical conditions or comparing digital and conventional techniques may provide a more comprehensive understanding of material behavior (Raja et al., 2024; García-Gil et al., 2020).

CONCLUSION

Within the limitations of this in vitro study, it was concluded that **polyvinyl siloxane (PVS)** exhibited the highest dimensional accuracy, best surface detail reproduction, and least number of impression defects compared to **polyether** and **condensation silicone**. Polyether showed satisfactory but slightly lower accuracy, while condensation silicone demonstrated the greatest dimensional changes and surface imperfections. Statistically significant differences ($p < 0.05$) confirmed that PVS is the most reliable and precise impression material for fixed prosthodontics. Therefore, PVS remains the preferred material for achieving optimal fit, accuracy, and clinical success in fixed prosthetic restorations.

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