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A Comparative Evaluation of Retentive Force in Maxillary Special Trays Using Different Final Impression Materials: An In Vivo Study

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Abstract:
Background: *Retention is a key determinant of success in complete denture prosthodontics, critically influenced by the accuracy of impression techniques and the materials employed.*
Aim: *To compare and evaluate the retentive forces required to dislodge maxillary special trays fabricated using different final impression materials following border moulding.*
Materials and Methods: *This in vivo study involved 10 completely edentulous patients. After standardized border moulding, three final impressions were made per patient using zinc oxide eugenol, zinc oxide non-eugenol, and addition silicone monophase. A digital force measurement system quantified the retention force for each impression. Data were statistically analysed using ANOVA, paired t-tests, and Tukey HSD post hoc analysis..*
Results: *Addition silicone monophase exhibited the highest mean retention (430.50 g), followed by zinc oxide non-eugenol (414.07 g), and zinc oxide eugenol (408.93 g). All materials significantly improved retention compared to border moulding alone (p < 0.01). However, no statistically significant differences were found among the three final impression materials (p > 0.05).*
Conclusion: *All tested impression materials significantly enhance denture retention beyond border moulding alone. While addition silicone showed the highest mean retention, the differences were not statistically significant, suggesting that clinical technique may outweigh material choice in determining overall retention.*
Key Word: *Denture retention, final impression materials, zinc oxide eugenol, addition silicone, border moulding, complete denture.*

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I. Introduction

One of the primary objectives of prosthetic dentistry is to enhance the performance of removable prostheses by improving their retention, stability, and support. These aspects are critically influenced by the accuracy of the impression-making process, which is fundamental to the success of complete denture therapy [1]. As outlined by Boucher, the five essential goals of complete denture impressions are: retention, stability, support, aesthetic outcome, and preservation of the residual ridge [2].

A precise impression depends significantly on proper tray selection, border moulding, and the use of materials with favourable physical and handling properties. Internal adaptation of the denture base to the residual ridge is crucial and may be compromised during processing, necessitating refined techniques and materials for optimal adaptation and resistance [3]. Retention, often described as the resistance to vertical dislodging forces, is one of the most critical and challenging aspects of denture success [4].

Factors affecting retention include the denture base area, the quantity and quality of saliva, adhesive and cohesive forces, interfacial surface tension, capillary attraction, and the anatomical features of the residual ridge [5]. Achieving optimal peripheral seal and adaptation without air entrapment requires meticulous border moulding followed by the application of a low-viscosity impression material [6]. While zinc oxide eugenol (ZOE) has been the gold standard due to its dimensional stability and accuracy, newer elastomeric materials like polyvinyl siloxane (PVS) are increasingly used and continually being refined [7].

Given that dimensional changes in impression materials can adversely affect denture fit and retention, this study aims to evaluate the retention of complete denture bases fabricated using different final impression materials, contributing to evidence-based improvements in complete denture prosthodontics.

II. Material And Methods

This in-vivo study was undertaken in the Department of Prosthodontics, Jaipur Dental College following approval from the institutional ethical and research committee. The aim of the study was to evaluate and compare the retentive forces required to dislodge maxillary custom trays fabricated using different final impression materials.

A total of ten completely edentulous patients (nine males and one female), aged between 45 and 60 years, were selected based on specific inclusion and exclusion criteria. Participants were required to be free from systemic illness and to have healthy oral mucosa, with no signs of inflammation or flabby tissue. Only patients who had lost their teeth due to periodontal disease were included. Exclusion criteria comprised patients with abnormal palatal vaults or deep undercuts, those with altered salivary flow (ropy saliva or xerostomia), patients undergoing radiation or chemotherapy, recent extractions, or unwillingness to participate [3].

For each patient, a non-perforated stock tray that extended approximately 5 mm beyond the residual ridge was chosen to make a preliminary impression of the maxillary arch using impression compound (Pyrax) [8]. The impressions were then poured in Type II gypsum (Kalabhai). On these models, a modified Boucher's spacer was fabricated using 2 mm thick modelling wax (MAARC) for zinc oxide eugenol (ZOE) and non-eugenol pastes, while a 4 mm thick wax spacer was used for addition silicone (monophase) impressions. Four orientation stops were incorporated into each spacer.

To fabricate the custom trays, cold mold seal (DPI) was applied to the models, and tray material (Pyrax) was pressed between two glass slabs to ensure uniform thickness, using a coin for reference. During polymerization, a 21-gauge wire hook was embedded at the geometric centre of the tray, determined by measuring the midpoint between the incisive papilla and the fovea palatinae. The custom trays were tried in the patients' mouths to confirm appropriate extension, which reached from one hamular notch to the other and extended approximately 2 mm beyond the vibrating line. A 2 mm clearance was maintained for border moulding material.

Border moulding for all trays was performed by the same operator using green stick compound (DPI) to ensure standardization and minimize operator variability.[9] After border moulding was completed, a preliminary retention test was carried out using a custom-made retention testing machine. Three trials were performed for each tray, and the average of the values was taken as the final result.

Following border moulding, wax spacers were removed and escape vents larger than 1 mm were made in the mid-palatal area using a round carbide bur, to relieve hydraulic pressure during impression-making [10]. Three different final impressions were made for each patient using the prepared custom trays:

1. Zinc oxide eugenol impression paste
2. Zinc oxide non-eugenol impression paste
3. Addition silicone (medium body)

Before making the addition silicone impression, tray adhesive was applied to ensure adequate bonding between the impression material and the tray. After each final impression was completed, the tray's retention was again assessed using the same custom retention testing device. The device used a pulley mechanism in which the wire attached to the hook in the tray passed through a lower and upper pulley and connected to a digital force sensor that displayed the applied force on an LCD screen. The dislodging force was applied vertically at the centre of the tray, a location chosen for its reliability in assessing retention [11]. During testing, the patient's head was stabilized in a natural position with the Frankfurt horizontal plane parallel to the floor [12]. Each impression underwent three retention tests, and the mean force value, recorded in grams, was documented as the final measure of retention.

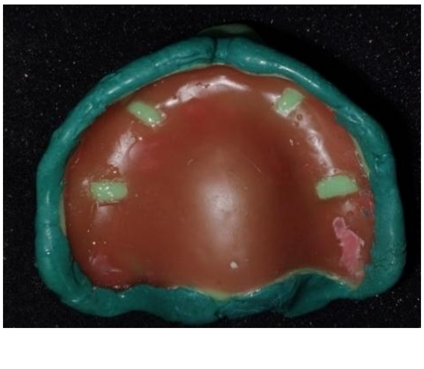


Figure 1: BORDER MOULDING

Figure 2: ZINC OXIDE EUGENOL IMPRESSION

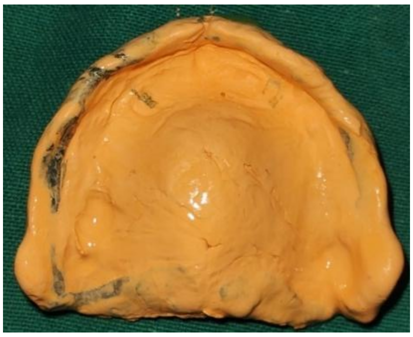


Figure 3: ZINC OXIDE NON-EUGENOL IMPRESSION

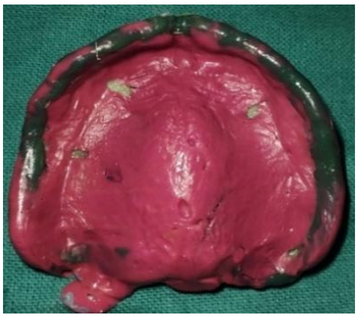


Figure 4: ADDITION SILICONE (MONOPHASE) IMPRESSION

[redacted]

Figure 5: Retention test being performed

Statistical analysis

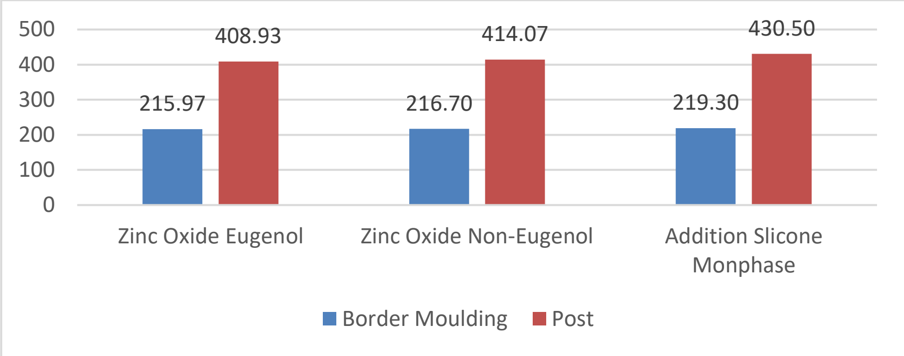
The data collected from the study were compiled using Microsoft Excel (v2019, Microsoft Corp.) and statistically analysed using IBM SPSS Statistics version 26.0. Paired t-tests were conducted to evaluate changes in retention within each group before and after the final impression. One-way Analysis of Variance (ANOVA) was used to compare retention values across the three impression materials: zinc oxide eugenol (ZOE), zinc oxide non-eugenol (ZON), and addition silicone. Tukey's Honest Significant Difference (HSD) test was applied as a post hoc analysis to determine the presence of any statistically significant differences between individual material groups. A p-value less than 0.05 was considered statistically significant for all analyses.

III. Results

A total of 10 completely edentulous patients (9 males and 1 female) were recruited for the study. Each participant underwent three final impression procedures using zinc oxide eugenol (ZOE), zinc oxide non-eugenol (ZON), and addition silicone impression materials, respectively. Mean retention values recorded for ZOE, ZON, and addition silicone were 408.93 g, 414.07 g, and 430.5 g, respectively [Table 1].

Table no 1 : MEAN OF BORDER MOULDING AND IMPRESSION

	Border Moulding	Post
Zinc Oxide Eugenol	215.97	408.93
Zinc Oxide Non-Eugenol	216.70	414.07
Addition Slicone Monphase	219.30	430.50



Paired t-test analysis revealed a statistically significant improvement in retention following the final impression across all three materials when compared to post-border moulding values ($p < 0.01$) [Table 2].

Table no2 : PAIRED 't' TEST.

		Mean	N	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean Difference	't'	p value
						Lower	Upper			
1	Border Moulding	215.9660	10	24.394	7.714	-213.334	-172.602	192.968	21.434	0.000
	Zinc Oxide Eugenol	408.9340	10	39.153	12.381					
2	Border Moulding	216.6990	10	25.864	8.179	-215.641	-179.093	197.367	24.433	0.000
	Zinc Oxide Non-Eugenol	414.0660	10	38.496	12.173					
3	Border Moulding	219.3000	10	24.551	7.764	-230.451	-191.947	211.199	24.816	0.000
	Addition Slicone Monphase	430.4990	10	41.019	12.971					

Significant changes are observed from Border Moulding for all the three materials as p value is found <0.01

One-way ANOVA showed no statistically significant difference among the three materials in terms of mean retention values ($p > 0.05$), although addition silicone demonstrated numerically higher retention [Table 3].

Table no3: One-way ANOVA Test

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Border Moulding	Between Groups	61.393	2	30.697	0.049	0.952
	Within Groups	16800.509	27	622.241		
	Total	16861.903	29			
After Final impression	Between Groups	2538.100	2	1269.050	0.810	0.455
	Within Groups	42276.814	27	1565.808		

	Total	44814.915	29			
Difference from Border Moulding	Between Groups	1810.791	2	905.395	1.242	0.305
	Within Groups	19684.824	27	729.068		
	Total	21495.614	29			

Tukey's HSD post hoc test confirmed that none of the pairwise comparisons among the materials were statistically significant, reinforcing the ANOVA findings [Table 4].

Table no4: TURKEY HSD TEST

Multiple Comparisons							
Tukey HSD							
Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Border Moulding	Zinc Oxide Eugenol	Zinc Oxide Non-Eugenol	-0.733	11.156	0.998	-28.392	26.926
		Addition Slicone Monphase	-3.334	11.156	0.952	-30.993	24.325
	Zinc Oxide Non-Eugenol	Zinc Oxide Eugenol	0.733	11.156	0.998	-26.926	28.392
		Addition Slicone Monphase	-2.601	11.156	0.971	-30.260	25.058
	Addition Slicone Monphase	Zinc Oxide Eugenol	3.334	11.156	0.952	-24.325	30.993
		Zinc Oxide Non-Eugenol	2.601	11.156	0.971	-25.058	30.260
After Final impression	Zinc Oxide Eugenol	Zinc Oxide Non-Eugenol	-5.132	17.696	0.955	-49.009	38.745
		Addition Slicone Monphase	-21.565	17.696	0.453	-65.442	22.312
	Zinc Oxide Non-Eugenol	Zinc Oxide Eugenol	5.132	17.696	0.955	-38.745	49.009
		Addition Slicone Monphase	-16.433	17.696	0.627	-60.310	27.444
	Addition Slicone Monphase	Zinc Oxide Eugenol	21.565	17.696	0.453	-22.312	65.442
		Zinc Oxide Non-Eugenol	16.433	17.696	0.627	-27.444	60.310
Difference from Border Moulding	Zinc Oxide Eugenol	Zinc Oxide Non-Eugenol	-4.399	12.075	0.930	-34.339	25.541
		Addition Slicone Monphase	-18.234	12.075	0.302	-48.174	11.706
	Zinc Oxide Non-Eugenol	Zinc Oxide Eugenol	4.399	12.075	0.930	-25.541	34.339
		Addition Slicone Monphase	-13.835	12.075	0.495	-43.775	16.105
	Addition Slicone Monphase	Zinc Oxide Eugenol	18.234	12.075	0.302	-11.706	48.174
		Zinc Oxide Non-Eugenol	13.835	12.075	0.495	-16.105	43.775

The small sample size may have limited the ability to detect significant differences among the groups. No significant interaction effects related to gender or anatomical variations were observed.
Each impression technique was repeated three times per patient, and the mean of the three readings was used to minimize operator and procedural variability. The retention force was recorded using a custom-designed retention testing machine standardized for vertical dislodgement force application.

IV. Discussion

Retention plays a critical role in the functionality and comfort of complete dentures, directly influencing speech, mastication, and aesthetics. Among the many contributing factors, the establishment of an effective peripheral seal through accurate border moulding remains foundational [5]. In this study, the focus was to evaluate the comparative retention provided by different final impression materials following standardized border moulding in completely edentulous patients.

The study confirmed that all three impression materials—zinc oxide eugenol (ZOE), zinc oxide non-eugenol (ZON), and addition silicone (monophase)—significantly enhanced denture retention beyond the levels achieved with border moulding alone. This reinforces the well-established notion that precise final impressions contribute measurably to the intimate adaptation of the denture base to the mucosa, facilitating an effective peripheral seal and improving prosthesis stability [13].

Although addition silicone exhibited the highest mean retentive value (430.50 g), followed closely by ZON (414.07 g) and ZOE (408.93 g), the differences among the materials were statistically insignificant. This suggests that while addition silicone may offer marginal advantages in retention, all materials tested can be considered clinically acceptable, aligning with previous findings by Drago (2003) [14] and Petrie et al. (2003) [15].

Addition silicone's superior retention can be attributed to its enhanced flow, hydrophilicity, and elastic recovery, which allow precise reproduction of surface detail and better adaptation to soft tissues. These findings are consistent with those of Fardos Rizk (2008) [16] and Solomon (2011) [17], who noted that silicone-based materials—especially monophase types—excel in tissue detail capture and long-term dimensional stability. Their ability to establish an effective surface tension interface and better adhesion further underpins their clinical effectiveness.

Zinc oxide eugenol, despite its rigidity, maintained competitive retentive performance due to its mucostatic nature and fine detail registration. However, it presents challenges such as post-insertion discomfort and difficulty in modification. Zinc oxide non-eugenol emerged as a viable alternative, particularly for eugenol-sensitive patients, offering comparable retention with improved comfort—a finding supported by Appelbaum and Mehra (1984) [18].

This study's findings are further strengthened by the methodological rigor employed. The use of custom trays with uniform spacer designs (Boucher, 2004) [3], consistent tray extensions, standardized border moulding, and a custom-built retention measuring apparatus ensured procedural consistency. Moreover, intra-subject comparisons minimized biological variability, enhancing the validity of the results.

Biomechanically, denture retention is a multifactorial phenomenon. Atmospheric pressure, adhesion, cohesion, mechanical interlocking, and surface tension collectively resist dislodgement forces. The closer the adaptation of the denture border to the dynamic soft tissues, the greater the retention achieved. These biomechanical principles were evident in the improved retention observed across all groups post-final impression, underlining the interplay between material properties and functional anatomy.

Interestingly, the statistically non-significant differences among materials may be attributed to the small sample size ($n = 10$), limiting the power to detect subtle differences. Future studies involving larger cohorts could reveal more definitive trends and may further stratify outcomes based on patient-specific anatomical or salivary characteristics.

The clinical relevance of conventional impression techniques remains intact despite recent advances in digital impressions. Studies by Chebib et al. (2022) [19] and Elkafrawy et al. (2022) [20] emphasized that conventional border-moulded impressions still provide superior retention over intraoral scans—supporting the continued use of these techniques in clinical practice.

V. Conclusion

In conclusion, while addition silicone demonstrated the highest mean retention, all evaluated materials showed statistically similar and clinically satisfactory results. The findings reaffirm the importance of border moulding and final impression accuracy in optimizing denture retention and support the continued use of conventional impression materials tailored to individual patient needs and preferences.

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