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Comparative evaluation of maxillary special tray retention using three different border molding materials for completely edentulous patients – An *in vivo* study

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Abstract:

Border molding is essential for establishing the peripheral seal and ideal extension needed to ensure complete denture retention, especially in the maxillary arch. Therefore, it is of interest to evaluate and compare the retention of maxillary complete denture fabricated with green stick compound, addition silicone and polycaprolactone for border moulding. Completely edentulous patients were randomly divided into three groups and retention of special tray was measured objectively using a force measurement technique. Polycaprolactone had the highest retention values where as addition silicone and green stick compound showed comparable retention ($p < 0.05$). Polycaprolactone can be considered the most effective border moulding material for improving retention of maxillary complete dentures. At the same time, addition silicone is a clinically acceptable alternative to the conventional green stick compound.

Keywords: Addition silicone, border molding, denture retention, polycaprolactone, green stick compound

Background:

Complete denture prosthodontics is aimed at restoring function, esthetics, comfort and confidence in completely edentulous patients. The success of a complete denture largely hinges on the precision of the impression procedure, which serves as the foundation for fabrication of the final prosthesis. Among the various stages involved, the final impression stage plays a pivotal role in achieving a well-fitting and retentive denture [1]. The final impression procedure for a complete denture involves recording the denture-bearing area and accurately capturing the functional depth and width of the vestibule through border molding, followed by impression of the edentulous arch. Border molding is defined as the process of shaping the borders of an impression tray by functional or manual manipulation of the surrounding soft tissues to duplicate the contour and extent of the vestibules [2]. Retention is a critical factor for the success of a maxillary complete denture and is defined as the resistance to displacement of the denture away from the supporting tissues [3]. Various factors influence denture retention, which may be broadly classified as biological, physical and mechanical. Among these, physical factors such as adhesion, cohesion, surface tension, atmospheric pressure and capillarity play a major role and are effective only when an adequate peripheral seal and posterior palatal seal are achieved. Terminating denture borders on soft, resilient tissues allows the mucosa to move in harmony with the denture during functional movements, thereby maintaining the peripheral seal and enhancing retention [4]. Conventionally, border molding has been performed using low-fusing impression compound. This technique involves sectional border molding, wherein different segments of the tray borders are molded in multiple applications. Although this method has been considered reliable and accurate, it is technique-sensitive, time-consuming and often uncomfortable for the patient. Multiple tray insertions were required to complete border molding using low-fusing compound, making the procedure

tedious and increasing the chances of error [5]. Additionally, the short working times, risk of distortion during reheating and potential for thermal injury to oral tissues-especially in inexperienced hands-are notable disadvantages. However, incremental border molding using low-fusing compound does not fulfil this requirement, as only a limited portion of the vestibule and associated musculature influences the tray borders during each insertion [6]. These limitations have resulted in the use of elastomeric impression materials in border molding procedures. Polysulphide, polyether and polyvinyl siloxane (PVS) materials have been suggested because of their improved accuracy, dimensional stability, ease of manipulation and satisfactory working and setting times. Disadvantages of these materials are odour and stain of polysulphide, inadequate manipulation time of polyether and thick and overextended borders with PVS with putty viscosity [2]. The polycaprolactone molding composition, which consists of a mixture of high and low molecular weight polycaprolactones, is excellent for creating dental impressions and models in general. It solidifies at 38°C and has a softening point that oral tissues can easily withstand. Improved impressions and models are made feasible by this kind of molding composition because of its low viscosity in the warm state and good rigidity in the cold state, particularly when modeling soft tissues and other pliable materials [7, 8]. Therefore, it is of interest to evaluate the retention of maxillary special trays fabricated with three different border-molding materials in completely edentulous patients.

Materials and Methods:

This study was conducted on 12 completely edentulous outpatients who reported to the Department of Prosthodontics, MES Dental College for complete denture treatment, after approval from the Institutional Ethics Committee (IEC/MES/101/24). The patients were selected based on the pre-defined eligibility criteria. The inclusion criteria were:

completely edentulous patients aged between 45 and 70 years and class 1 soft palate. (According to Mallampati classification). The exclusion criteria were: thin and atrophied ridges, flabby tissues, severe bilateral undercuts, patients reporting after recent extraction (less than 3 months), those with uncontrolled systemic diseases or pathological conditions of mucosa and underlying bone, neuromuscular disorders or hyperactive gag reflex. The selected participants were randomly allocated to three groups according to the border molding material used: Group 1: Green stick impression compound; Group 2: Putty consistency addition silicone; and Group 3: Polycaprolactone

Primary impression and diagnostic cast:

For all participants, a primary impression was made using impression compound (Dental Products of India, PINNACLE Functional Impression Compound). The impression was poured using Type II dental plaster (POP Powder IP, Ram Raju Surgical Cotton Mills Ltd., India) to obtain a diagnostic cast.

Fabrication of special trays:

All the undercuts in the diagnostic casts were blocked out using plaster before the adaptation of the wax spacer. For each patient, three custom special trays were fabricated using auto polymerizing acrylic resin (DPI RR Cold Cure Acrylic Resin, Dental Products of India). A uniform spacer thickness of 2 mm was provided using Sharry's full spacer design with modelling wax (Hindustan Modelling Wax No. 2). The spacer was positioned such that it was 2 mm short of the functional sulcus and maintained 4 mm away from the deepest part of the sulcus. After fabrication, a U-loop made from an 8 cm long 19-gauge stainless steel wire was attached to the anterior mid-palatal region corresponding to a line joining the distal surfaces of the canines. The loop was secured to the special tray using cold-cure acrylic resin in the dough stage, prepared with one standard scoop of PMMA powder and 2.5 mL of monomer. This loop served as the point of force application during retention testing. Each patient therefore received three identical special trays.

Grouping based on border molding material:

The fabricated trays were divided into three groups: Group 1: Border molding was performed using green stick tracing compound (DPI PINNACLE Tracing Sticks, Dental Products of India). Group 2: Border molding was done using putty-consistency addition silicone (Flexceed Vinyl Polysiloxane, GC India Pvt. Ltd.) after applying tray adhesive (Coltene VPS adhesive). Group 3: Border molding was carried out using polycaprolactone thermoplastic material (HOMTOPY Tooth Repair Shaping Teether Kit).

Manipulation of green stick:

Green stick compound is manipulated by softening it over a Bunsen burner or in a water bath until it becomes pliable. The softened material is then adapted along the borders of the custom tray, tempered in warm water to prevent tissue injury and molded intraorally by functional manipulation of the

surrounding oral tissues.

Manipulation of putty addition silicone:

Addition silicone putty (polyvinyl siloxane) is manipulated by mixing equal volumes of base and catalyst with nitrile-gloved fingertips for about 30–45 seconds until a uniform, streak-free color is obtained. It has a working time of approximately 2 minutes and a setting time of 4–5 minutes.

Manipulation of polycaprolactone:

Heating Phase: Polycaprolactone beads were immersed in a temperature-regulated hot water bath (approximately 55–60°C). The beads would change from an opaque white colour to a translucent, clear appearance to show they were ready for manipulation. **Kneading phase:** The softened material was taken out with sterile tweezers and gently kneaded with wet fingers until a homogeneous, pliable mass was obtained. Moist fingers did not adhere and allowed smooth handling; **Shaping Phase:** The softened mass was rolled into a thin cylindrical rope form of uniform diameter.

Adaptation to tray borders:

Material was adapted all over the periphery of the special tray borders. Care was taken to verify that the tray borders were dry so as to promote adequate adhesion of the material to the acrylic tray. The silicone for the putty addition was treated by roughening the borders of the tray and applying tray adhesive before adding the material.

Border molding procedure:

Each material was used as recommended by the manufacturer. The tray was placed in the patient's mouth and functional activities like lip movement, cheek manipulation, tongue movement and functional action of the mandible were guided to accurately shape the borders. The material was set intraorally on cooling and thus recorded the functional depth and width of the sulcus. If overextension or under extension was detected, the material was reheated and readapted, which is a major advantage of polycaprolactone and greenstick compound. For the final and complete setting of greenstick compound and polycaprolactone, the tray was placed in cold water after border molding. In the case of putty-addition silicone, care was taken to avoid easy dislodgement of the putty material from the tray borders. For each patient, the border molding procedures with the three materials were carried out on three separate consecutive days to minimize patient fatigue and operator variability.

Final impression procedure:

After completion of border molding, the wax spacer was removed. Three relief holes of 2mm diameter were placed in the mid-palatine region to allow escape of excess impression material and prevent pressure build-up. The final impression was made using light-body polyvinyl siloxane (Flexceed VPS, GC India Pvt. Ltd.).

Measurement of retention:

Retention was evaluated by applying a downward dislodging force to each tray through the 19-gauge stainless steel loop attached to the tray. The force required to dislodge the tray was measured using a digital force gauge with a hook attachment. During the measurement, the patient was seated in an upright position. The retention force was recorded in kilograms (kg).

Standardization of procedure:

To ensure uniformity, all procedures were performed by the same operator under the same clinical environment using identical armamentarium. All patients were given standardized instructions for performing functional border movements during the procedure.

Statistical analysis:

All collected data were systematically entered into Microsoft Excel and subsequently analyzed using IBM SPSS Statistics Version 24.0. The ANOVA and Tukey's post-hoc analysis were used to contrast the mean retentive force and mean number of tray insertions done at a 5% level of significance.

Results:

In the present research, retentive force values of the three study groups were analysed using descriptive statistics and one-way ANOVA. The Green stick group (n = 12) showed a mean retentive force of 1.22 ± 0.28 kg, with values ranging from 0.83 to 1.52 kg. The retentive force of the Putty addition silicone group was 1.14 ± 0.29 kg. The group of Polycaprolactone showed the highest retentive force with a mean value of 1.68 ± 0.32 kg ($F = 11.442$, $p < 0.001$). This suggested that the type of material used had a significant effect on the retention force, with polycaprolactone having more retention than green stick and putty addition silicone (**Table 1**). Post-hoc multiple comparison

using Tukey's HSD test was performed to determine the pairwise differences in retentive force between the three groups. The comparison between Green stick (1.22 ± 0.28 kg) and Putty addition silicone (1.14 ± 0.29 kg) showed a mean difference of 0.08 kg, which was not statistically significant ($p = 0.791$). A statistically significant difference was observed between Green stick (1.22 ± 0.28 kg) and Polycaprolactone (1.68 ± 0.32 kg), with a mean difference of -0.46 kg ($p = 0.002$). Similarly, the comparison between Putty addition silicone (1.14 ± 0.29 kg) and Polycaprolactone (1.68 ± 0.32 kg) indicated that polycaprolactone had significantly greater retentive force than putty addition silicone (**Table 2**). A statistically significant difference in tray insertion was observed among the three groups (ANOVA: $F = 306.786$, $p < 0.001$). The Green stick group exhibited the highest tray insertion with a mean of 6.92 ± 0.90 , ranging from 5 to 8 tray insertions. In contrast, the Putty addition silicone group showed a considerably lower mean tray insertion number of 2.08 ± 0.29 . The Polycaprolactone group demonstrated the lowest tray insertion, with a mean of 1.25 ± 0.45 . Overall, these findings indicate that tray insertion number varied substantially depending on the material used, with Green Stick requiring substantially more tray insertions than Putty addition silicone and Polycaprolactone (**Table 3**). The Green stick group had a significantly greater tray insertion number than the Putty addition silicone group ($p < 0.001$) and the Polycaprolactone group ($p < 0.001$). Additionally, the Putty addition silicone group demonstrated a significantly higher number of tray insertions than the Polycaprolactone group ($p = 0.005$). These findings indicate a clear hierarchical pattern in tray usage, with Green stick requiring the greatest number of tray insertions, followed by Putty addition silicone, while Polycaprolactone required the least (**Table 4**).

Table 1: Comparison of mean retentive force among the three study groups

Groups	N	Retentive force (Mean $\pm$ SD Kg)	95% CI		Minimum	Maximum	F-test (ANOVA)	p-value
			Lower bound	Upper bound				
Green stick	12	1.22 ± 0.28	1.04	1.39	0.83	1.52	11.442	0.000**
Putty addition silicone	12	1.14 ± 0.29	0.95	1.32	0.67	1.56		
Polycaprolactone	12	1.68 ± 0.32	1.47	1.88	1.20	2.00		
Total	36	1.34 ± 0.38	1.21	1.47	0.67	2.00		

Table 2: Multiple comparison of mean retentive force among the three study groups using Tukey HSD post hoc test

I groups	J groups	Mean difference (I - J) Kg	SE	p-value	95% CI	
					Lower bound	Upper bound
Green stick	Putty addition silicone	0.08	0.12	0.791	-0.22	-0.38
	Polycaprolactone	-0.46	0.12	0.002**	-0.76	-0.16
Putty addition silicone	Green stick	-0.08	0.12	0.791	-0.38	0.22
	Polycaprolactone	-0.54	0.12	0.000**	-0.84	-0.24
Polycaprolactone	Green stick	0.46	0.12	0.002**	0.16	0.76
	Putty addition silicone	0.54	0.12	0.000**	0.24	0.84

Table 3: Comparison of mean number of tray insertions done

Groups	N	Mean $\pm$ SD (number of tray insertion)	95% CI		Minimum	Maximum	F-test (ANOVA)	p-value
			Lower bound	Upper bound				
Green stick	12	6.92 ± 0.90	6.34	7.49	5	8	306.786	0.000**
Putty addition silicone	12	2.08 ± 0.29	1.90	2.27	2	3		
Polycaprolactone	12	1.25 ± 0.45	0.96	1.54	1	2		
Total	36	3.42 ± 2.60	2.54	4.30	1	8		

Table 4: Multiple comparison of mean number of tray insertions done among the three study groups using Tukey HSD post hoc test

I groups	J groups	Mean difference (I - J) Kg	SE	p-value	95% CI	
					Lower bound	Upper bound
Green stick	Putty addition silicone	4.83	0.25	0.000**	4.23	5.44
	Polycaprolactone	5.67	0.25	0.000**	5.06	6.27
Putty addition silicone	Green stick	-4.83	0.25	0.000**	-5.44	-4.23
	Polycaprolactone	0.83	0.25	0.005**		
Polycaprolactone	Green stick	-5.67	0.25	0.000**		
	Putty addition silicone	-0.83	0.25	0.005**		

Discussion:

Retention is one of the major factors affecting the success of complete dentures. Retention is especially important in the maxillary arch and an adequate peripheral seal is necessary to stabilise the prosthesis during function. Border moulding is necessary to record the functional depth and width of the vestibule, which is important for the construction of dentures with ideal extension and border adaptation. Green stick impression compound has been used as the traditional gold standard in border moulding; however, the introduction of elastomeric materials and thermoplastic polymers has provided clinicians with alternatives with better physical and handling characteristics [5]. This study was designed to compare the retention of maxillary complete dentures fabricated with green stick compound, addition silicone and polycaprolactone as border moulding materials. The results showed that polycaprolactone had the highest value of retention, whereas addition silicone and green stick compound have almost similar retention values. There were statistically significant differences among the groups, which indicate that physical properties of border moulding materials have a direct effect on the quality of peripheral seal and consequently denture retention. Polycaprolactone showed better performance than the other materials in this study, possibly due to its thermoplastic properties and its ability to accommodate the dynamic movements of oral tissues. Polycaprolactone softens at relatively low temperatures (around 60°C), allowing a long working time and repeated manipulation without significant degradation of the material properties [9]. Polycaprolactone can be moulded continuously along the border with little distortion, while traditional green stick compounds set quickly and may require incremental additions. This allows a more accurate documentation of the functional vestibular anatomy and is beneficial for an improved peripheral seal. Recent reviews on complete denture impression materials have shown that thermoplastic polymers have better adaptation, less patient discomfort and improved dimensional accuracy compared to conventional border moulding compounds [10]. The better retention with polycaprolactone is also consistent with the biomechanical principles for complete denture success. Retention is dependent on intimate adaptation of the denture base to the supporting tissues, effective border seal, interfacial surface tension, adhesion, cohesion and atmospheric pressure. A well-formed border minimises air leakage under the denture base and thus maximises these forces. Probably, the good flow properties of the polycaprolactone in the functional pressure lead to a better reproduction of the vestibular tissues and muscle attachments, leading to an improved peripheral seal [2]. Similar

observations have been reported in a prior study [10] that emphasise the importance of accurate border moulding for optimum denture retention and satisfaction of the patient. In the present study, the addition silicone shows better retention values with reduced number of tray insertion. This finding is clinically significant as addition silicone possesses many desirable physical properties including excellent dimensional stability, high elastic recovery, minimum polymerisation shrinkage and high reproduction of detail. Addition silicone, as opposed to green stick compound, records borders in one step and does not require multiple reheating, thus reducing operator variability. These properties have led to the acceptance of elastomeric materials for border moulding in complete denture practice. Addition silicone provides more accurate peripheral extension as compared to the impression compound and also increased patient comfort and reduced chairside time have been reported by several recent clinical studies [11]. However, the lower retention compared to polycaprolactone may be due to the fact that elastomeric materials cannot be functionalised repeatedly after polymerisation [12]. The lower retention obtained in the present study with green stick compound is consistent with the limitations of this material. Impression compound has been used for decades because it is cheap and readily available [13], but it has some disadvantages of its own. The procedure is quite technique-sensitive due to the need for repeated heating and incremental application of the material. Unequal heating may lead to non-uniform flow and repeated manipulation may produce false recording or distortion of tissue dynamics. Also, fast cooling decreases the working time and hence the probability of incomplete functional moulding. These factors can lead to inadequate peripheral seal and reduced denture retention. Green stick compound is a dependable material, but experts recognise its utility and propose that newer materials might provide improved consistency and precision in the clinical situation [14]. One of the key strengths of the present study is the use of an objective force-measuring method in the evaluation of denture retention. Many past studies have used subjective clinician evaluation or patient-reported satisfaction, which are both subject to bias. Objective measurement of dislodgement force gives reliable and measurable data for meaningful comparison of materials. In fact, there has been a growing trend in contemporary prosthodontic research to include objective retention tests alongside patient-reported outcome measures for a thorough assessment of the performance of complete dentures [15, 16]. The current results also have substantial clinical significance. Border moulding is one of the most operator-sensitive operations in complete denture fabrication. The increasing precision of material manipulation may result in

major improvements in treatment outcomes, particularly for the less experienced general practitioner [17]. Polycaprolactone also offers a range of practical advantages such as being re-heatable, simple to correct, minimal waste and long working time. Such features can increase adaptation at the margin and reduce chairside therapeutic modifications and remakes. Addition silicone is easy to manipulate and has good dimensional stability, which makes it a suitable material for normal prosthodontic practice. Thus, in addition to tradition, clinicians may utilise scientific proof of their clinical performance when choosing border moulding materials [18]. The present findings also align with the current trend toward digital complete denture workflows. Digital denture manufacturing is gaining relevance, but still conventional impression techniques are necessary to record the functional vestibular anatomy in many clinical situations. Border moulding continues to be an important component of the denture fabrication process with digital technologies and contemporary standards of practice suggest that material selection continues to affect the quality of definitive impressions and prosthesis retention [19–21]. Therefore, in modern prosthodontics, optimisation of traditional border moulding materials is still very relevant. The results are significant, although there are some limitations in the interpretation of the results. The sample size was small and only maxillary complete dentures were analysed. Patient factors such as salivary flow, ridge morphology, mucosal resilience, neuromuscular control and long-term tissue adaptation may also influence denture retention. Moreover, the retention was evaluated immediately after the fabrication of dentures and long-term clinical performance and patient satisfaction were not studied. Future multicentre randomised clinical trials with larger sample sizes, longer follow-up periods, incorporation of patient-reported outcome measures and comparison with digital border moulding techniques would provide stronger evidence regarding the clinical superiority of different border moulding materials.

Conclusion:

Polycaprolactone outperformed addition silicone and conventional green stick compound in retention, probably due to its favourable thermoplastic nature, excellent adaptability and more accurate recording of functional vestibular anatomy. Addition silicone also showed clinically acceptable retention (with minimum number of tray insertion) may be an acceptable alternative where ease of handling and dimensional stability is desired. Green stick compound remains a popular material due to its familiarity and low cost.

Advancement to knowledge:

This study compared the retention of maxillary complete dentures made with green stick compound, addition silicone and polycaprolactone for border moulding. Polycaprolactone showed the greatest retention, while addition silicone and green stick compound performed similarly.

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