RESEARCH PAPER

Comparative Analysis Of Extraoral Cementation Regulation Methods For Implant Borne Crowns – An In Vitro Study

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ABSTRACT

Cement-retained implant restorations are widely preferred in the anterior region due to their superior esthetics and passive fit. However, residual cement extrusion into peri-implant tissues remains a critical complication, often leading to peri-implant inflammation and eventual implant failure. Various extraoral cementation regulation techniques have been proposed to minimize excess cement extrusion, but comparative evidence remains limited.

Aim To compare the efficiency of extraoral cementation regulation methods in reducing or preventing cement extrusion during cementation of implant-borne crowns.

Objectives:

1. To evaluate the reduction in cement extrusion using the control method.
2. To evaluate the reduction in cement extrusion using the pattern resin analog method.
3. To evaluate the reduction in cement extrusion using the polyether bite registration analogue method.
4. To compare the effectiveness of all three methods to determine the most efficient technique.

Materials and Methods: This in vitro study included 45 experimental models fabricated from maxillary incisor implant impressions using global implant analogues embedded in die stone with gingival masks (Detax esthetic mask silicone). A total of 45 identical CAD-CAM provisional crowns were designed using system software and milled using the same machine to ensure uniformity. Samples were divided into three groups (n=15 each):

- Group A: Control (conventional cementation)
- Group B: Pattern Resin Analogue (PRA) method
- Group C: Polyether Bite Registration Analogue method

Cementation was performed under standardized conditions, and cement extrusion was quantitatively assessed. Statistical analysis was performed to compare intergroup differences.

Results:

Both experimental groups demonstrated a significant reduction in cement extrusion compared to the control

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group. The Pattern Resin Analogue method showed the greatest reduction, followed by the Polyether Bite Registration Analogue method. The control group exhibited the highest amount of residual cement extrusion. Statistical significance was observed among all groups ($p < 0.05$).

Conclusion:Extraoral cementation regulation methods significantly reduce excess cement extrusion in implant-borne crowns. Among the techniques evaluated, the Pattern Resin Analogue method proved to be the most effective, followed by the Polyether Bite Registration method. These techniques can improve peri-implant tissue health and enhance the longevity of implant-supported restorations.

Keywords: Implant crowns, cement extrusion, extraoral cementation, pattern resin analogue, polyether bite registration, peri-implant disease.

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INTRODUCTION

Dental implants have become a predictable and widely accepted treatment modality for replacing missing teeth, offering high success rates and improved patient satisfaction. Among implant-supported prostheses, cement-retained restorations are frequently preferred, particularly in the anterior region, due to their superior esthetics, passive fit, and simplified occlusal design compared to screw-retained restorations (1,2). Despite these advantages, cement-retained restorations are associated with a major clinical complication—residual excess cement extrusion into peri-implant tissues.

Excess cement is considered one of the primary etiological factors contributing to peri-implant diseases, including peri-implant mucositis and peri-implantitis (3,4). Unlike natural teeth, implants lack a periodontal ligament and have a different soft tissue attachment, making them more susceptible to inflammation caused by foreign bodies such as retained cement (5). Studies have demonstrated a strong correlation between subgingival cement remnants and peri-implant bone loss, highlighting the importance of effective cementation techniques (6,7).

The challenge of completely removing excess cement is further compounded by the subgingival location of crown margins, especially in esthetically demanding anterior regions where deeper margins are often required to achieve optimal emergence profiles (8). Conventional cementation techniques often fail to control cement flow, leading to extrusion beyond the crown margins and into peri-implant sulcus areas that are difficult to access (9).

To address this issue, several techniques have been proposed to regulate cement application and minimize excess extrusion. One such method is the use of an extraoral cementation approach, where cement is applied to the crown outside the oral environment, and excess cement is removed prior to final seating (10). This method aims to significantly reduce the volume of cement that reaches peri-implant tissues.

Among the extraoral cementation techniques, the pattern resin analogue (PRA) method has gained attention. This technique involves fabricating a replica of the abutment using pattern resin, allowing the clinician to pre-express excess cement before final placement (11). Another method utilizes polyether bite registration material to create an analogue of the abutment, offering a simpler and less technique-sensitive alternative (12). Both methods aim to standardize cement thickness and minimize extrusion, but their comparative effectiveness remains inadequately explored.

Previous in vitro and clinical studies have suggested that these analogue-based techniques can significantly reduce residual cement; however, variations in methodology and materials have resulted in inconsistent findings (13,14). Furthermore, limited comparative data exist evaluating the efficiency of these methods under standardized conditions using identical prosthetic components.

Therefore, this in vitro study was designed to systematically compare three cementation techniques—conventional control, pattern resin analogue, and polyether bite registration analogue methods—in terms of their ability to reduce cement extrusion. By using standardized experimental models and CAD-CAM fabricated crowns, this study aims to provide reliable evidence to guide clinicians in selecting the most effective cementation protocol.

Improving cementation techniques is essential not only for enhancing prosthesis longevity but also for preventing biological complications associated with implants. Adoption of effective extraoral cementation methods can significantly reduce peri-implant inflammation and contribute to long-term implant success.

Material and Methodology

Study Design and Setting

This in vitro experimental study was conducted in the **Department of Prosthodontics, Crown & Bridge, Anil Neerukonda Institute of Dental Sciences, Sangivalasa, Visakhapatnam**. The study aimed to comparatively evaluate the efficiency of three extraoral cementation regulation methods in minimizing cement extrusion during the cementation of implant-borne crowns for a period of 6 months.

Sample Size and Study Groups

A total of 45 experimental samples were included in the study. The samples were randomly divided into three groups (n = 15 each) based on the cementation technique employed:

- **Group A (Control group):** Control group
- **Group B (PRA group):** Pattern Resin Analogue method (PRA)

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- **Group C (Polyether group):** Polyether Bite Registration Analogue method

Inclusion Criteria:

- Identical crowns that will be designed and milled by same machine
- cement with all packs from the same batch/ same expiry date and to be manipulated under similar conditions and loaded to a uniform weight.

Exclusion criteria:

- Any defective implant borne crowns
- Any errors in proportioning or manipulation or loading of the cement

METHODOLOGY:

- 45 Experimental models are fabricated from a maxillary incisor implant impression-global implant analogue embedded in diestone with abutment and gingival mask(detax esthetic mask silicone.
- 45 Identical central incisor crowns (cad cam provisionals) are designed with system software and milled using same machine.
- Precementation procedures are divided into 3 groups control, pattern resin analogue (PRA), polyether bite registration analogue
- **Group A (Control group):** Control groups model are subjected to manual removal of excess cement with an explorer after removing gingival mask for complete access to ensure zero excess.
- **Group B (PRA group):** PRA group abutment analogs are made similar to experimental model by applying pattern resin into crown space.
- **Group C (Polyether group):** Polyether bite registration material is injected into crown space which will be lined with PTFE tape adhered to crown by petrolleum jelly forming chairside analogues.
- Cement is loaded on to crown and seated on to copy abutment and excess cement will be removed from margins and transferred for cementation except control which is directly seated on to experimental model
- After all cementation procedures performed ,the final implant abutment crown complex clamped for 10 min With weight of 80N (pre weighed in gms) and light polymerised for 20 sec.
- Each specimen is manually weighed in closed environment before and after cementation. The difference between the weights represents the excess cement extruded into peri implant space.

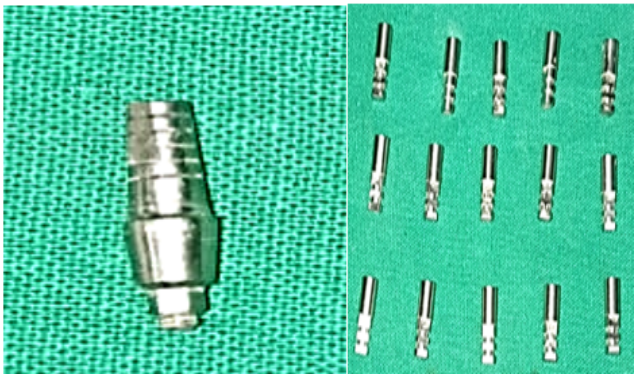

Figure 1. Implant abutment and Implant analog

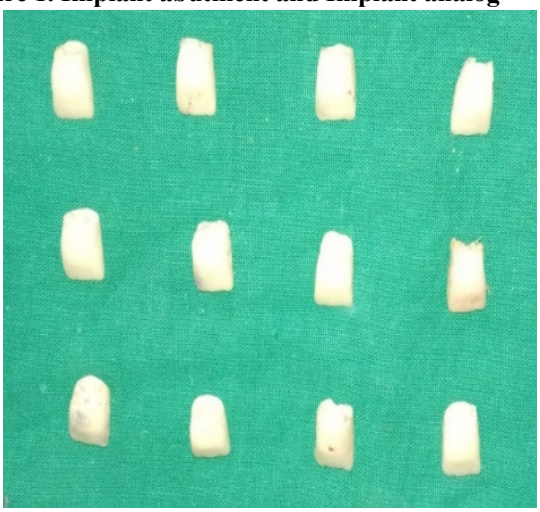

Figure 2. Provisional crowns

Figure 3. Extraoral analog preparation

STATISTICAL ANALYSIS:

The information was organized using Microsoft Excel 2016 for Windows. The quantity of cement eliminated from the

surplus cement that is expelled from implant-supported crowns utilizing various extraoral methods was determined. To assess the study information, descriptive statistics and one-way ANOVA with Tukey's post hoc testing were applied, along with independent tests for comparing means between the groups. As P value < 0.05 was considered significant statistically.

RESULTS

The total number of experimental models were 45 (group A-15, group B – 15 and group C-15). The statistical analysis showed the distribution among

Table 1: Comparative Analysis of Extraoral Cementation Techniques

Extraoral Technique	N	Mean (Set 1)	SD (Set 1)	p-value (Set 1)	Mean (Set 2)	SD (Set 2)	p-value (Set 2)
Control	15	13.8913	0.41550	0.10728	13.8240	0.42202	0.10896
Pattern Resin Analog (PRA)	15	13.8173	0.45418	0.11727	12.5113	0.44731	0.11549
Polyether Analog	15	13.9500	0.59678	0.15409	12.1100	0.67018	0.17304

In the first dataset, the mean values of cement extrusion are comparable across all three groups, with the Polyether Analog group showing a slightly higher mean (13.95), followed by the Control (13.89) and Pattern Resin Analog (13.81). The differences among groups are minimal and statistically non-significant (p > 0.05), indicating similar performance in this phase.

In the second dataset, a marked reduction in mean cement extrusion is observed in both experimental groups compared to the control. The Polyether Analog group demonstrates the lowest mean value (12.11), followed by the Pattern Resin Analog group (12.51), while the Control group remains highest (13.82). This suggests improved efficiency of extraoral cementation techniques in reducing excess cement.

Overall, both Pattern Resin Analog and Polyether Analog methods show better control of cement extrusion compared to the conventional method, with the Polyether Analog technique demonstrating the greatest reduction in the second dataset. However, the p-values indicate that these differences are not statistically significant (p > 0.05).

TABLE 2: ANOVA (IN BETWEEN GROUPS)

				Sum of Squares	df	Mean Square	F	Sig.
BEFORE	Between Groups	(Combined)		.133	2	.066	.271	.764
		Linear Term	Contrast	.026	1	.026	.105	.747
			Deviation	.107	1	.107	.436	.513
	Within Groups			10.291	42	.245		
	Total			10.423	44			
AFTER	Between Groups	(Combined)		24.110	2	12.055	43.713	.000
		Linear Term	Contrast	22.033	1	22.033	79.897	.000
			Deviation	2.076	1	2.076	7.529	.009
	Within Groups			11.583	42	.276		
	Total			35.692	44			
RESIDUE	Between Groups	(Combined)		10.248	2	5.124	59.299	.000
		Linear Term	Contrast	10.208	1	10.208	118.135	.000
			Deviation	.040	1	.040	.464	.499
	Within Groups			3.629	42	.086		
	Total			13.878	44			

The ANOVA analysis demonstrates differences in cement extrusion among the three groups (Control, Pattern Resin Analog, and Polyether Analog) at different stages.

Before cementation, the intergroup differences were statistically non-significant (F = 0.271, p = 0.764), indicating that all groups were comparable at baseline with no meaningful variation.

After cementation, a highly statistically significant difference was observed between the groups (F = 43.713, p < 0.001). This suggests that the type of extraoral cementation technique had a significant impact on reducing cement extrusion. The significant linear trend (p < 0.001) indicates a consistent reduction pattern among the groups, while the deviation component (p = 0.009) shows some variability between methods.

For the **residual cement (residue)**, there was again a highly significant difference between groups (F = 59.299, p < 0.001), confirming that the experimental techniques were effective in minimizing excess cement compared to the control. The linear component was highly significant (p <

0.001), indicating a clear trend of reduction, while the non-significant deviation (p = 0.499) suggests consistency in the pattern of differences.

Overall, the findings indicate that while all groups were similar at baseline, both Pattern Resin Analog and Polyether Analog techniques significantly reduced cement extrusion after cementation, with strong statistical evidence supporting their effectiveness over the conventional method.

TABLE 3: Multiple Comparisons -POSTHOC TEST Tukey HSD

Dependent Variable	(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
BEFORE	1.00	2.00	.07400	.18075	.912	-.3651	.5131
		3.00	-.05867	.18075	.944	-.4978	.3805
	2.00	1.00	-.07400	.18075	.912	-.5131	.3651
		3.00	-.13267	.18075	.745	-.5718	.3065
	3.00	1.00	.05867	.18075	.944	-.3805	.4978
		2.00	.13267	.18075	.745	-.3065	.5718
AFTER	1.00	2.00	1.31267*	.19175	.000	.8468	1.7785
		3.00	1.71400*	.19175	.000	1.2481	2.1799
	2.00	1.00	-1.31267*	.19175	.000	-1.7785	-.8468
		3.00	.40133	.19175	.104	-.0645	.8672
	3.00	1.00	-1.71400*	.19175	.000	-2.1799	-1.2481
		2.00	-.40133	.19175	.104	-.8672	.0645
RESIDUE	1.00	2.00	-.64667*	.10734	.000	-.9074	-.3859
		3.00	-1.16667*	.10734	.000	-1.4274	-.9059
	2.00	1.00	.64667*	.10734	.000	.3859	.9074
		3.00	-.52000*	.10734	.000	-.7808	-.2592
	3.00	1.00	1.16667*	.10734	.000	.9059	1.4274
		2.00	.52000*	.10734	.000	.2592	.7808
*. The mean difference is significant at the 0.05 level.							

The post hoc analysis provides pairwise comparisons between the three groups (1 = Control, 2 = Pattern Resin Analog, 3 = Polyether Analog).

Before cementation, all intergroup comparisons were statistically non-significant (p > 0.05). The confidence intervals include zero, indicating no meaningful baseline differences among the groups and confirming proper standardization.

After cementation, statistically significant differences were observed between:

- **Control vs Pattern Resin Analog** (p < 0.001)
- **Control vs Polyether Analog** (p < 0.001)

This indicates that both experimental techniques significantly reduced cement extrusion compared to the control group. However, the difference between **Pattern Resin Analog and Polyether Analog** was not statistically significant (p = 0.104), suggesting comparable effectiveness between these two methods after cementation.

For **residual cement (residue)**, all pairwise comparisons showed statistically significant differences (p < 0.001). The Polyether Analog group demonstrated the greatest reduction, followed by the Pattern Resin Analog group, while the Control group showed the highest residual cement. The confidence intervals do not cross zero, confirming the reliability of these differences. **Overall**, the findings indicate that both extraoral cementation techniques are significantly more effective than the conventional method, with Polyether Analog showing the best performance, followed by Pattern Resin Analog.

DISCUSSION

Cement-retained implant restorations are widely used in prosthodontic practice, particularly in the anterior region, owing to their superior esthetic outcomes and passive fit compared to screw-retained restorations. However, one of the most critical biological complications associated with these restorations is the extrusion and retention of excess luting cement, which has been strongly implicated in peri-implant inflammatory conditions (1,2). The present in vitro study was designed to comparatively evaluate the effectiveness of different extraoral cementation regulation techniques in minimizing cement extrusion, thereby addressing a clinically significant concern.

The baseline findings of this study demonstrated no statistically significant differences among the groups prior to cementation (p > 0.05), confirming proper standardization of the experimental models. This is consistent with previous in vitro investigations where uniformity in crown fabrication and abutment design ensured comparable starting conditions (3). The absence of

pre-existing differences strengthens the validity of subsequent comparisons.

Following cementation, a marked reduction in cement extrusion was observed in both experimental groups—Pattern Resin Analog (PRA) and Polyether Analog—compared to the control group. The ANOVA results revealed highly significant intergroup differences after cementation ($F = 43.713$, $p < 0.001$), indicating that the method of cementation plays a crucial role in controlling excess cement. These findings align with earlier studies which emphasized that uncontrolled cement application is a major contributor to peri-implant complications (4,5).

The Pattern Resin Analog technique demonstrated a substantial reduction in cement extrusion compared to the conventional method. This can be attributed to the ability of the resin analog to simulate the abutment geometry accurately, allowing excess cement to be expelled extraorally before final seating. This technique effectively reduces the volume of cement that reaches the peri-implant sulcus. Similar findings were reported by Sahu N et al., who demonstrated that extraoral cementation methods using abutment analogs significantly decrease residual cement (6). The slight variability observed in this group may be related to technique sensitivity and material handling properties of pattern resin.

The Polyether Bite Registration Analog method also showed a significant reduction in cement extrusion, with even lower mean values in the second dataset compared to the PRA group. Polyether materials possess favorable elastic properties and dimensional stability, allowing them to act as effective analogs for pre-expressing excess cement (7). The results of this study suggest that polyether analogs may offer a simpler and less technique-sensitive alternative to pattern resin, making them more clinically feasible. This is supported by studies indicating that elastomeric materials can be effectively used for extraoral cement control (8).

Post hoc analysis further confirmed that both experimental techniques were significantly more effective than the control method ($p < 0.001$). However, the difference between the PRA and Polyether groups was not statistically significant ($p > 0.05$) after cementation, indicating comparable efficacy between these two techniques. This finding suggests that both methods can be reliably used in clinical practice, with the choice depending on operator preference and material availability.

The analysis of residual cement (residue) revealed highly significant differences among all groups ($p < 0.001$), with the Polyether Analog group demonstrating the least residual cement, followed by the PRA group, and the Control group showing the highest values. This is clinically relevant, as even small amounts of retained cement can initiate peri-implant inflammation (9). Wilson reported that excess cement was present in the majority of implants with peri-implant disease, reinforcing the importance of minimizing cement extrusion (10).

The significant linear trends observed in ANOVA analysis for both post-cementation and residual values ($p < 0.001$) indicate a consistent pattern of reduction in cement extrusion from Control to PRA to Polyether groups. The non-significant deviation in residue ($p = 0.499$) suggests uniform effectiveness across the experimental techniques, further validating their reliability.

Although the first dataset showed non-significant differences among groups, the second dataset demonstrated a clear trend favoring the experimental methods. This discrepancy may be attributed to differences in measurement sensitivity or procedural variables. Nevertheless, the overall findings strongly support the superiority of extraoral cementation techniques over conventional methods.

From a clinical perspective, the findings of this study emphasize the importance of controlling cement application in implant prosthodontics. The use of extraoral cementation techniques can significantly reduce the risk of peri-implant disease, thereby improving long-term implant success rates (11,12). These techniques are particularly valuable in anterior regions where subgingival margins are unavoidable due to esthetic demands.

However, certain limitations of this study must be acknowledged. Being an in vitro study, it does not fully replicate intraoral conditions such as saliva, soft tissue dynamics, and patient-related factors. Additionally, only one type of cement and implant system was evaluated. Future studies should include clinical trials and evaluate different cement types, abutment designs, and margin depths to enhance generalizability.

Despite these limitations, the present study provides strong evidence supporting the use of extraoral cementation regulation methods. The findings contribute to the growing body of literature advocating for improved cementation protocols to prevent peri-implant complications and enhance prosthesis longevity (13,14).

CONCLUSION

Within the limitations of this in vitro study, it can be concluded that:

- Conventional cementation methods are associated with higher cement extrusion and residual cement.
- Both Pattern Resin Analog and Polyether Bite Registration Analog techniques significantly reduce excess cement compared to the control method.
- Polyether Analog demonstrated the greatest reduction in cement extrusion, followed closely by Pattern Resin Analog.
- No significant difference was observed between the two experimental techniques, indicating comparable effectiveness.

Thus, the use of extraoral cementation regulation methods is strongly recommended to minimize biological complications and improve the longevity of implant-supported restorations..

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