EVALUATION OF TENSILE BOND STRENGTH OF IMPLANT SUPPORTED RESTORATIONS USING VARIOUS LUTING TECHNIQUES: AN IN-VITRO STUDY

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ABSTRACT

Purpose: This in-vitro study aimed to evaluate the tensile bond strength of implant-supported restorations cemented with glass ionomer cement using four luting techniques: complete fill, half/partial fill, vent hole, and resin abutment replica.

Methods: Forty cobalt-chromium implant abutments and corresponding metal copings fabricated by Direct Metal Laser Sintering were mounted on acrylic resin blocks with implant analogs and divided into four groups of 10. Each group received Type I glass ionomer cement using one of the four cementation protocols, and tensile bond strength was measured with a universal testing machine.

Results: The vent hole and half-fill techniques showed the highest mean tensile bond strength, followed by the complete fill technique, while the resin abutment replica group had the lowest bond strength. Techniques allowing controlled cement escape appeared to reduce hydraulic pressure and improve retention.

Conclusions: Within the limits of this in-vitro study, the vent hole and half-fill techniques provided a better balance between tensile bond strength and cement control for glass ionomer-cemented implant-supported restorations. These methods may help optimize retention while reducing residual cement, though further in-vivo studies are needed.

Keywords: Implant-supported restorations, Luting techniques, Tensile bond strength, Glass Ionomer Cement.

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INTRODUCTION

Osseointegration revolutionized implant dentistry, providing the foundation for predictable implant-supported restorations. Retention between restoration and abutment critically influences the success of fixed implant prostheses; factors include restorative material, surface area, abutment taper, surface treatment, and—most importantly—the luting cement. Compared with natural teeth, implant abutments often present smoother, more tapered surfaces and reduced cross-sectional area, which can limit mechanical retention and increase reliance on the adhesive and mechanical properties of cements.

Common luting agents—zinc phosphate, glass ionomer, resin-based, and zinc oxide–eugenol—differ markedly in tensile bond strength (TBS) and clinical behavior. Resin cements generally provide the highest bond strength and durability, glass ionomer offers chemical adhesion but lower tensile strength and moisture sensitivity, zinc phosphate provides rigidity without chemical bonding, and ZOE is suited for temporary luting due to low tensile strength. (1-6) Studies indicate that cement type and surface interactions (for example, cobalt-chromium copings bonded to titanium abutments) affect long-term retention, partly via surface roughness and abrasiveness.

Additive-manufactured Co–Cr alloys (DMLS/SLM) show superior mechanical and microstructural properties versus cast alloys, and changes in abutment or coping fabrication can influence prosthesis retention.

Clinically, cementation technique also affects retention, retrievability, and peri-implant health; excess cement can provoke peri-implant inflammation. Various cementation methods—venting, abutment replicas, complete fill, and partial fill—aim to optimize cement control and retention, but their effects on TBS remain unclear. (11-13)

This in vitro study compares four luting techniques using glass ionomer cement to determine their impact on tensile bond strength of implant-supported restorations, with the goal of informing clinical choices that balance retention, retrievability, and peri-implant tissue health.

MATERIALS AND METHODOLOGY

Study Design:
An in vitro study evaluated the tensile bond strength (TBS) of implant-supported restorations cemented with glass ionomer cement (GIC) using four luting techniques. Forty specimens were fabricated and allocated into four groups (n = 10 each): Complete Fill (CF), Half/Partial Fill (HF), Vent Hole (V), and Abutment Replica (AR).
Materials:

- Modelling wax (Hindustan modelling wax no. 2; HDP, India)
- Addition silicone putty (Zhermack Hydrorise Putty, Italy)
- Clear autopolymerizing acrylic resin (DPI-RR Cold Cure, India)
- Pink autopolymerizing acrylic resin (DPI-RR Cold Cure, India)
- Implant analogs (Alpha Bio Tec, Israel)
- Straight Co–Cr abutments (DMLS fabricated)
- Co–Cr metal copings with hook (DMLS fabricated)
- Glass ionomer cement (GC Gold Label 1 / Fuji I; GC Corporation, Tokyo, Japan)

Armamentarium and Equipment:
Scale, silicone mixing cup, acrylic trimming burs, mixing paper pad, plastic and agate spatulas, petroleum jelly, gauze, and Universal Testing Machine (Matrix MET-T-50).
Specimen fabrication:

- Wax pattern and mold: A rectangular wax pattern (15 mm × 20 mm) was fabricated, invested in addition silicone putty to produce a mold.
- Acrylic resin blocks: Clear cold-cure acrylic resin was mixed and poured into the putty mold with an implant analog inserted before polymerization. Forty resin blocks were prepared, trimmed, finished, and polished.
- Digital design and DMLS fabrication: Resin blocks with implant analogs were scanned (extraoral scanner) and abutments designed in EXOCAD (straight abutment, 6.2 mm length × 3.5 mm width). A 20 µm spacer was provided; metal copings with an occlusal hook (14.2 mm height × 6.7 mm width; 5.7 mm hollow between hooks) were designed. Abutments and copings were fabricated by DMLS, finished, polished, and their fit verified on the implant analogs. External surfaces of abutments and internal surfaces of copings were sandblasted.

Abutment replicas and vent holes:

- For AR group: A putty index of the implant abutment was taken and filled with pink cold-cure acrylic to produce abutment replicas.
- For V group: A vent hole was prepared on the occlusal surface of copings to allow cement extrusion.

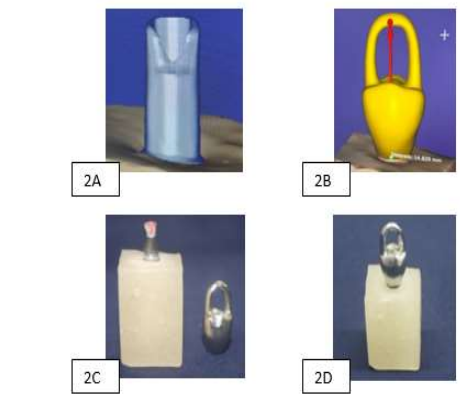
Grouping and Luting Procedure:
Forty specimens were randomized into four groups (n = 10):

1. Complete Fill (CF): Copings were fully loaded with GIC (GC Gold Label 1 / Fuji I) mixed at 1:2 (powder/liquid) ratio and seated on the abutment with hand compression for 5 minutes. Excess cement at margins was removed after setting.
2. Half/Partial Fill (HF): GIC (1:2) was applied by brushing onto the axial walls of the coping only; copings were seated and hand-compressed for 5 minutes. Marginal excess was removed after setting.
3. Vent Hole (V): Copings were filled to the margin with GIC (1:2) and seated; extruded cement was expressed through the occlusal vent and removed immediately with gauze. Marginal excess was removed after setting.
4. Abutment Replica (AR): Copings were fully filled with GIC (1:2) and initially seated on the resin abutment replica. After removal and cleanup of excess cement, copings were then seated on the implant abutment and hand-compressed for 5 minutes. Marginal excess was removed after setting.

All manual seating used consistent hand compression technique and timing across groups.

Testing:

After cementation and setting, tensile bond strength of each specimen was measured using a Universal Testing Machine (Matrix MET-T-50) by applying tensile load through the coping hook until failure. The peak load at debonding was recorded and used to calculate TBS. Results were analyzed using one-way ANOVA.



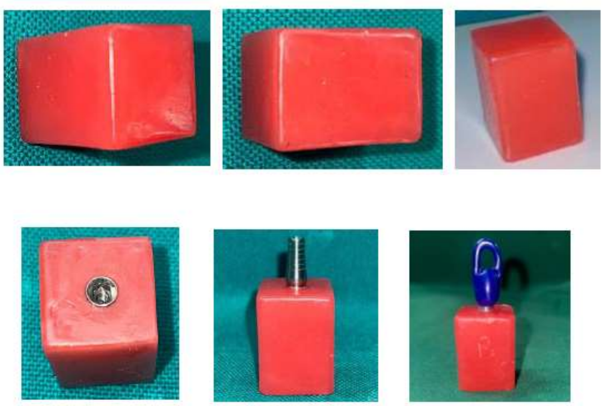


Figure No: 6 – Abutment Replica Technique

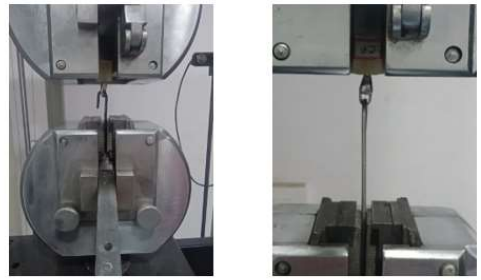


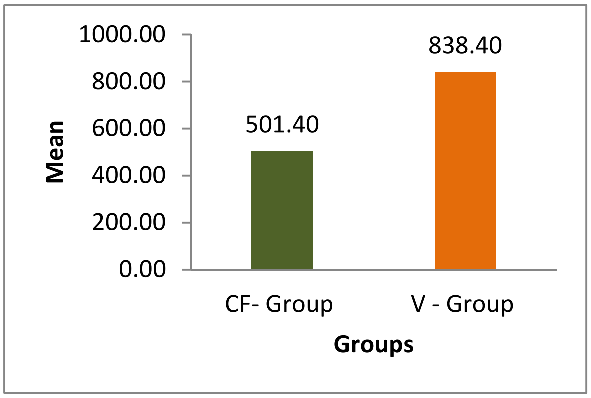
Figure No: 7 – Universal Testing Machine

RESULTS AND OBSERVATIONS

This in vitro study assessed the tensile bond strength (TBS) of implant-supported restorations cemented with GIC using four luting techniques (n = 10 per group): Complete Fill (CF) — copings filled to the margin; Half/Partial Fill (HF) — cement applied to axial walls only; Vent Hole (V) — occlusal vent provided for cement extrusion; Abutment Replica

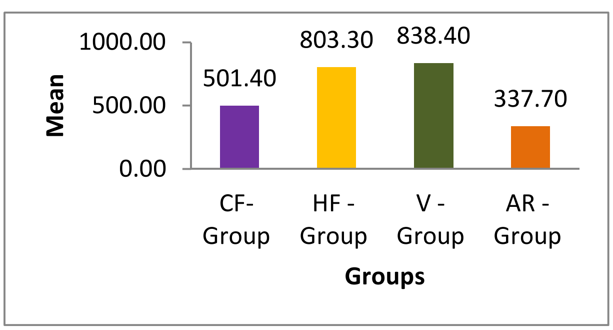
(AR) — copings initially cemented on a resin abutment replica, removed, then seated on the implant abutment.

Data were analyzed with one-way ANOVA to compare group means. When ANOVA was significant, pairwise comparisons were performed using Tukey's HSD (post-hoc). Statistical significance was set at $P < 0.05$.



"Table 1: Mean comparison of Tensile Bond Strength among CF, HF, V and AR Groups.

Groups	N	Minimum	Maximum	Mean	SD	P value
CF	10	100	892	501.40	335.40	0.001 S
HF	10	146	1131	803.30	279.84	
V	10	235	1301	838.40	298.78	
AR	10	90	743	337.70	253.88	



Statistical Analysis: ANOVA one way test. S: Statistically significant if $P<0.05$; NS: Not-significant."

Graph 1: Mean comparison of Tensile Bond Strength among CF, HF, V and AR Groups.

"Table 2: Mean comparison of Tensile BS between CF - Group and HF- Group.

Statistical Analysis: Tukey HSD test. S: Statistically significant if $P<0.05$; NS: Not-significant".

Groups	Min	Max	Mean	SD	Mean difference	P value
CF	100	892	501.40	335.40	301.90	0.117 NS
HF	146	1131	803.30	279.84		

Graph 2: Mean comparison of Tensile Bond Strength between CF - Group and HF - Group

"Table 3: Mean comparison of Tensile BS between CF - Group and V- Group.

Groups	Min	Max	Mean	SD	Mean difference	P value
CF	100	892	501.40	335.40	337.00	0.066 NS
V	235	1301	838.40	298.78		

Statistical Analysis: Tukey HSD test. S: Statistically significant if $P<0.05$; NS: Not-significant."

Graph 3: Mean comparison of Tensile BS between CF - Group and V – Group

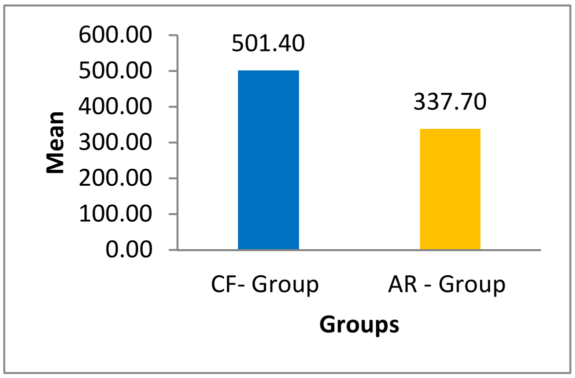
"Table 4: Mean comparison of Tensile BS between CF - Group and AR- Group.

Groups	Min	Max	Mean	SD	Mean difference	P value
CF	100	892	501.40	335.40	163.70	0.062 NS

AR	90	74 3	337. 70	253. 88		

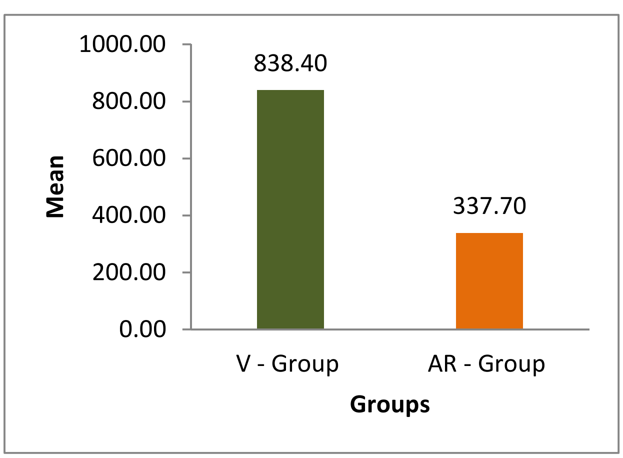
Statistical Analysis: Tukey HSD test. S: Statistically significant if $P<0.05$; NS: Not-significant."

Graph 4: Mean comparison of Tensile Bond Strength between CF - Group and AR – Group



"Table 5: Mean comparison of Tensile BS between HF - Group and V- Group.

Gro ups	**Mi n**	**M ax**	**Mea n**	**SD**	**Mean differe nce**	**P valu e**
HF	14 6	11 31	803. 30	279. 84	35.10	0.99 3. NS
V	23 5	13 01	838. 40	298. 78		



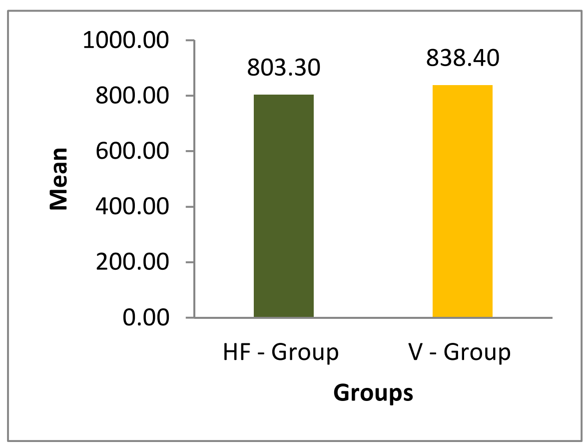
Statistical Analysis: Tukey HSD test. S: Statistically significant if $P<0.05$; NS: Not-significant."

Graph 5: Mean comparison of Tensile Bond Strength between HF - Group and V - Group

"Table 6: Mean comparison of Tensile BS between HF - Group and AR- Group.

Grou ps	Mi n	Ma x	Mea n	SD	Mean differe nce	P valu e
HF	14 6	11 31	803. 30	279. 84	- 465.60	0.00 6 S
AR	90	74 3	337. 70	253. 88		

Statistical Analysis: Tukey HSD test. S: Statistically significant if $P<0.05$; NS: Not-significant."

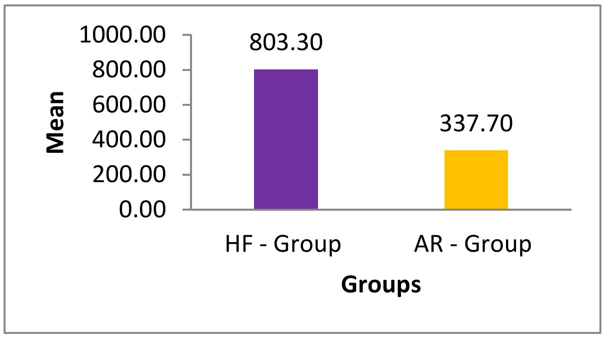


Graph 6: Mean comparison of Tensile Bond Strength between HF - Group and AR - Group

“Table 7: Mean comparison of Tensile BS between V - Group and AR- Group.

Groups	Min	Max	Mean	SD	Mean difference	P value
V	235	1301	838.40	298.78	500.70	0.003 S
AR	90	743	337.70	253.88		

Statistical Analysis: Tukey HSD test. S: Statistically significant if $P<0.05$; NS: Not-significant.”



Graph 7: Mean comparison of Tensile Bond Strength between V - Group and AR - Group

DISCUSSION

Study overview:
This in vitro study assessed tensile bond strength (TBS) of implant-supported restorations cemented with glass ionomer cement using four luting techniques: Complete Fill (CF), Half/Partial Fill (HF), Vent Hole (V), and Resin Abutment Replica (AR) (n = 10 per group). DMLS-fabricated Co–Cr abutments and copings ensured standardized specimens. TBS was measured using a universal testing machine. One-way ANOVA and Tukey HSD were used; significance set at $p < 0.05$.

Key findings:

- Luting technique significantly affected TBS ($p = 0.001$).
- Mean TBS (N): V = 838.40, HF = 803.30, CF = 501.40, AR = 337.70.
- Vent Hole and Half-Fill techniques produced the highest retention and were significantly greater than AR (Tukey HSD).
- Complete Fill showed moderate TBS; AR exhibited the lowest TBS.

Interpretation:

- Venting and partial-fill reduce hydraulic pressure during seating, promote uniform seating, and improve cement escape, yielding stronger, more consistent cement films and higher TBS.
- Complete bulk filling may generate hydrostatic resistance that impedes full seating and reduces bond strength.
- Abutment-replica pre-seating, while effective at limiting excess cement, appears to thin or displace the cement layer and significantly reduces retention—highlighting a trade-off between cement control and mechanical retention.

Material and method considerations:

- Use of DMLS Co–Cr components provided precise, repeatable abutment/coping geometry and reliable surface characteristics, strengthening internal validity.
- Being an in vitro study, results do not fully replicate intraoral conditions (saliva, thermal cycling, occlusal loading); clinical extrapolation should be cautious.

Clinical implications:

- For GIC-cemented implant restorations, Vent Hole and Half-Fill techniques offer superior retention while allowing cement management, and may better balance retrievability and peri-implant health than Abutment-Replica methods.
- Clinicians must weigh retention needs against the risk of residual cement; controlled cement delivery (venting or partial filling) is recommended to optimize both retention and cement control.

Limitations

- In vitro conditions did not replicate the oral environment (saliva, pH changes).
- No aging simulations (thermocycling, long-term water storage) or dynamic/mechanical fatigue loading were performed.
- Testing used static tensile loading (UTM), which does not mimic cyclic masticatory forces.
- Only one luting agent (GIC) was evaluated, limiting generalizability to other cements.
- A single abutment type (straight Co–Cr) was used, so results may not apply to other materials or geometries.

Recommendation: Future studies should include thermocycling, cyclic loading, multiple cement types, and varied abutment designs to improve clinical relevance.

CONCLUSION

Cementation technique significantly influences tensile bond strength of GIC-luted implant restorations. Vent Hole and Half-Fill methods provided the highest TBS, Complete Fill yielded intermediate values, and Abutment Replica produced the lowest retention. These findings support preferring controlled cement delivery techniques to achieve optimal retention and minimize excess cement.

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