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Fracture resistance of five interim crown materials: An *in vitro* study

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Abstract:

Interim crowns require adequate fracture resistance to withstand functional masticatory loads during provisional treatment. Therefore, it is of interest to compare the five provisional materials using 25 standardized DMLS dies under compressive loading. Ultimate force, break force and break distance were measured and analyzed using one-way ANOVA and Kruskal-Wallis tests ($\alpha=0.05$). Heat-cure PMMA showed the highest fracture resistance, whereas light-cure resin showed the lowest values ($P<0.05$). Thus, heat-cure PMMA is recommended for long-term provisionalization, while bis-acryl resins are suitable alternatives and light-cure resin should be avoided in stress-bearing posterior areas.

Keywords: Interim crown, fracture resistance, polymethyl methacrylate (PMMA), bis-acryl, provisional restoration, *in vitro*, computer-aided design and computer-aided manufacturing (CAD/CAM)

Background:

Interim restorations are indispensable components of fixed prosthodontic treatment, serving to maintain esthetics, occlusal stability, pulpal protection and patient comfort during the transition to definitive restorations. According to the Glossary of Prosthodontic Terms, an interim restoration is designed to enhance form, function and esthetics for a limited duration before placement of the definitive prosthesis [1]. The mechanical success of interim restorations is largely determined by the physical properties of the material selected. PMMA-based materials have historically been popular due to their ease of manipulation and low cost; however, heat-cure and self-cure PMMA differ significantly in polymer conversion and residual monomer content, which directly affects their mechanical performance [2]. Bis-acryl composite resins incorporate pre-polymerized fillers that improve flexural strength and reduce polymerization shrinkage. Light-cure acrylics, while clinically convenient, often exhibit lower fracture resistance due to incomplete photopolymerization and weaker resin networks [3]. Fracture resistance is a critical parameter because provisional crowns encounter repetitive occlusal loads and parafunctional stresses [4]. Materials with inadequate strength may fracture prematurely, compromising function and treatment outcomes. Heat-polymerized PMMA exhibits superior mechanical properties because of higher polymer chain conversion and structural homogeneity [5]. Bis-acryl materials have shown favorable performance attributable to their reinforced resin matrix [6]. Digital workflows improve accuracy, reproducibility and standardization in the fabrication of interim restorations. CAD/CAM-fabricated prototypes provide consistent dimensions and morphological precision [7]. Therefore, it is of interest to report the fracture resistance of five commonly used interim crown materials under standardized *in vitro* conditions.

Materials and Methods:**Study design:**

An *in vitro* comparative laboratory study. Ethical approval was not required as any human subjects or biological specimens were involved.

Sample size determination:

Based on previously published fracture resistance values of provisional crown materials, power analysis (power 99%, $\alpha=.05$) indicated a minimum of 5 specimens per group, yielding a total sample of 25 specimens.

Specimen preparation:

A mandibular molar (#36) typodont was prepared for an all-ceramic crown following standard guidelines. A digital impression was obtained using Primescan (Dentsply Sirona, York, Pa) and a master crown was designed in Exocad Dental CAD 3.1 (Exocad GmbH, Darmstadt, Germany). Twenty-five identical metal dies were fabricated using Direct Metal Laser Sintering (DMLS), selected for its dimensional accuracy and reproducibility. A vinyl polysiloxane index (Neosil; Medicept Dental, UK) fabricated from the master crown standardized wall thickness and external contour across all groups.

Materials tested:

Five interim crown materials were evaluated: Group I – Heat-cure PMMA (Pyrax Polymars, Roorkee, India); Group II – Self-cure PMMA (Pyrax Polymars, Roorkee, India); Group III – Light-cure resin (GC Corp, Tokyo, Japan); Group IV – Protemp 4 (3M ESPE, St Paul, Minn) bis-acryl composite; Group V – Integrity (Dentsply Sirona, York, Pa) bis-acryl composite. All materials were handled per manufacturer instructions.

Cementation:

All crowns were cemented onto the DMLS dies using Meta NetC non-eugenol temporary cement (Meta Biomed, Cheongju, South Korea) with a constant seating pressure of 5 kg for the manufacturer-recommended setting time.

Fracture resistance testing:

A universal testing machine (Tinius Olsen H50KL; Tinius Olsen Ltd, Horsham, Pa) applied axial compressive force at 1 mm/min until catastrophic failure. Ultimate force (N), break force (N) and break distance (mm) were recorded for each specimen.

Statistical analysis:

Data were analyzed using R software v4.2.2 (R Foundation for Statistical Computing, Vienna, Austria). Normality was assessed with the Shapiro-Wilk test. Normally distributed data were

analyzed with one-way ANOVA and Tukey HSD post hoc test; non-normal data with Kruskal-Wallis and Dunn post hoc test. Significance was set at $\alpha=.05$.

Results:

Significant differences were observed among all five groups for all tested parameters ($P<.05$). Heat-cure PMMA demonstrated the highest ultimate force (2.69 ± 0.00 N) and break force (2.67 ± 0.02 N), followed by Integrity (2.65 ± 0.00 N), self-cure PMMA (2.61 ± 0.00 N) and Protemp 4 (2.14 ± 0.00 N). Light-cure resin demonstrated markedly inferior fracture resistance with an ultimate force of only 0.13 ± 0.00 N ($P<.001$ vs all groups). Self-cure PMMA exhibited the greatest break distance (0.95 ± 0.00 mm), indicating plastic deformation before failure. Results are summarized in **Table 1**.

Table 1: Mean $\pm$ SD values of fracture resistance parameters by material group

Material	Ultimate Force (N)	Break Force (N)	Break Distance (mm)
Heat-cure PMMA	$2.69 \pm 0.00^*$	$2.67 \pm 0.02^*$	0.70 ± 0.00
Integrity	2.65 ± 0.00	2.63 ± 0.01	0.71 ± 0.00
Self-cure PMMA	2.61 ± 0.00	2.60 ± 0.01	$0.95 \pm 0.00^\dagger$
Protemp 4	2.14 ± 0.00	2.12 ± 0.01	0.71 ± 0.00
Light-cure resin	$0.13 \pm 0.00^\ddagger$	$0.11 \pm 0.01^\ddagger$	0.76 ± 0.00

*Highest value; † Greatest break distance; ‡ Lowest value ($P<.001$ vs all groups).

Discussion:

This study showed significant variation in fracture resistance across five interim crown materials. Heat-cure PMMA showed the highest resistance, attributed to superior polymer chain conversion, homogeneity and reduced residual monomer content compared with self-cure alternatives. Self-cure PMMA exhibited lower resistance, consistent with its faster exothermic polymerization cycle that yields greater porosity and a less homogeneous polymer network. Bis-acryl materials (Protemp 4 and Integrity) showed intermediate performance, aligning with evidence of enhanced fracture resistance due to inorganic filler reinforcement and lower polymerization shrinkage [8]. Light-cure resin showed the weakest mechanical performance, supporting earlier literature attributing low strength to incomplete photopolymerization and lower molecular weight networks. The ultimate force of 0.13 N raises serious concerns about its use in posterior stress-bearing regions. Digital specimen fabrication using DMLS improved intergroup standardization, minimizing morphological variability [9]. While CAD/CAM-milled interim restorations were not independently tested, prior studies report superior marginal precision and consistent mechanical performance with milled provisional materials [10].

Conclusion:

Heat-cure PMMA showed the highest fracture resistance among the five interim crown materials tested, while light-cure resin was the weakest. Bis-acryl composite resins showed moderate, clinically acceptable performance. Material selection for interim crowns should account for expected duration of

provisionalization, anticipated occlusal loads and the mechanical properties of the material.

Limitations:

This study was conducted under controlled *in vitro* conditions without thermocycling or cyclic fatigue loading, limiting direct clinical extrapolation. Only one tooth morphology was evaluated, sample size per group was limited to five specimens and only axial loading was applied. Future studies should incorporate fatigue testing, thermocycling and multiple tooth forms.

Clinical implications:

Heat-cure PMMA is recommended for long-term interim restorations. Bis-acryl composite resins (Protemp 4 and Integrity) are appropriate for short- to medium-term provisionalization. Light-cure resin should be avoided in posterior regions subject to significant occlusal loading.

Advancement of knowledge:

This study is the first to use standardized DMLS metal dies with a CAD/CAM-verified master crown to compare five interim crown materials under identical conditions, eliminating the morphological variability that confounds conventional comparative studies. By demonstrating a 20-fold difference in fracture resistance between heat-cure PMMA and light-cure resin under standardized compressive loading, this investigation provides actionable evidence-based guidance for material selection in interim crown provisionalization across varying clinical durations and occlusal demand scenarios.

Null hypothesis: There is no significant difference in the fracture resistance among the five interim crown materials tested.

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Conflict of interest: The authors declare no conflict of interest.

Ethical approval: Ethical approval was not required as any human subjects or biological specimens were involved in this *in-vitro* study.

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