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Evaluation of Flexural Strength and Microhardness of Milled Vs 3d Printed Provisional Restorative Materials for Fixed Prosthesis- An Invitro Study

Sasi Sree Sowmya Satyavolu

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ABSTRACT

Aim: This in vitro study aimed to evaluate and compare the flexural strength and surface microhardness of provisional fixed partial dentures (FPDs) fabricated using 3D-printed resins and CAD/CAM-milled PMMA materials.

Materials and Methods: Thirty three-unit provisional FPDs were fabricated and divided into two groups (n=15): Group A – 3D-printed using Ackuretta CURO resin, and Group B – milled using PMMA blocks (UPSERA). Flexural strength was measured using a universal testing machine through a three-point bending test. Microhardness was evaluated using a Vickers microhardness tester.

Results: Group B (milled) showed significantly higher flexural strength (298.67±74.82 MPa) compared to Group A (3D-printed) (67.60±11.44 MPa) (p=0.000). Similarly, the Vickers microhardness values were significantly higher for the milled group (21.73±1.33) than for the 3D-printed group (17.33±1.29) (p=0.000).

Conclusion: CAD/CAM-milled provisional restorations demonstrated superior mechanical properties compared to 3D-printed counterparts, suggesting greater suitability for long-term provisional applications.

Keywords: 3D printing, CAD/CAM, provisional prosthesis, flexural strength, microhardness, PMMA.

I. INTRODUCTION

Provisional restoration plays a vital role throughout the period of its use in theoral cavity. They should protect pulpal tissue from physical, biochemical, and thermal damage, maintain positional stability and occlusal function, and offer strength, retention, and beauty to prepared teeth. They can also be used to adjustan uneven occlusal plane, establish vertical dimensions, and contouring the gingival tissue.[1]

Aside from its immediate protective, functional, and stabilizing benefits, interim restorations are important for diagnostic purposes, where functional, occlusal, and esthetic parameters are constructed to find an optimal treatment outcome prior to the completion of definitive operations. [2]

Extensive prosthetic therapy necessitates provisional restorations with excellent mechanical strength for long-term use. When restorations replace multiple teeth over a lengthy period of time, the prosthesis's strength and stability are crucial, or the fractures may occur, where fracture strength of temporary restorations is closely related to the flexuralstrength,Elasticmodulus.[1]

Traditionally, many procedures and materials have been created to give an interim restoration that is aesthetically pleasing, simple to build, and, most importantly, of great strength and hardness. The materials used to fabricate single and multiple unit provisional restorations are generally resin-based. They differ in polymerization process, filler mix, and monomer type. Materials used include poly(methyl methacrylate) (PMMA), poly(ethyl methacrylate), polyvinyl (ethylmethacrylate), bisphenol Agycidyl methacrylate, bis-acryl resin composites, and urethanedi- methacrylate resins,etc[3].Provisional materials with high flexural strength and microhardness are crucial for long-termuse,and long-span prostheses.[3]

The use of three-dimensional (3D)-printed temporary dental restorations in clinical settings is increasing as a result of rapid 3D printing capabilities, simple dental computer-aided design (CAD) software, and the widespread availability of intraoral scanning technology.[4]In the field of dentistry, it has garnered a lot of attention recently. It has transformed dental restorations, particularly temporary ones [5,6]. Using technology in the production of dental prosthesis is preferable to more traditional procedures such as the lost-wax process because of its cost-effectiveness, lower carbon emissions, and material and energy saving [7].

Polymethyl methacrylate (PMMA) has long been considered the material of choice for provisional prosthetic restorations in fixed prosthodontics, primarily due to its advantageous properties. These include ease of manipulation,

cost-effectiveness, biocompatibility, and acceptable esthetic outcomes. PMMA is versatile and has been widely used in various forms—self-cure, heat-cure, and more recently, CAD/CAM and 3D-printed variants. However, traditional PMMA, especially when processed through self-cure or heat-cure techniques, presents certain drawbacks. These conventional methods often result in increased polymerization shrinkage, residual monomer release, and internal porosity, which can negatively impact the mechanical properties, dimensional stability, and longevity of the restoration. These limitations have prompted the development and clinical adoption of pre-polymerized PMMA blocks and alternative digital fabrication techniques to improve consistency and performance.[24]

Furthermore, provisional restorations provide temporary support, protection, and aesthetics while final restorations performed [8], and they rely on factors like as flexural strength to ensure that abutment teeth remain stable during the interim period[9].

Flexural strength, or the material's capacity to bend without breaking, is required for dental restorations to withstand forces during mastication. 3D printing technology facilitates the creation of interim repairs by utilizing a range of resins, each with its own composition, curing processes, and physical properties. These changes may have an impact on the flexural strength of temporary restorations [11].

Dental practitioners can ensure the longevity and durability of restorations by analyzing their flexural strength [12.] This evaluation guides materials and production procedures, ensuring patient happiness and optimal performance. Furthermore, by better understanding the elements that influence flexural strength, 3D-printed temporary restorations can be developed and manufactured with a higher clinical success rate [13]. As a result, the current study aimed to critically assess and synthesize the body of research on the flexural strength of temporary restorations created using 3D printing and diverse resins.

The purpose of this study is to examine the mechanical properties—specifically, the flexural strength and microhardness—of provisional FPDs made using 3D printing and CAD/CAM milling.

II. METHODOLOGY

Sample Size and Grouping

A total of 30 three-unit provisional fixed dental prostheses (FP)
Ds) were fabricated and equally divided into two groups:

- **Group A (n=15)**: Provisional FPDs fabricated using **3D-printed** resin (ACKURETTA CURO).
- **Group B (n=15)**: Provisional FPDs fabricated using **CAD/CAM-milled** polymethyl methacrylate (PMMA) blocks (UPSERA).

Each group contained 15 identical prostheses to allow for statistically meaningful comparisons of flexural strength and surface hardness.

Tooth Preparation and Digital Workflow

1. A **typodont model** was used to simulate a clinical case.
2. Tooth preparations were done on the **left first premolar and first molar** to fabricate a three-unit FPD:
   - Occlusal reduction: 1.5–2 mm
   - Axial reduction: 1 mm
   - Taper: 6° convergence
   - Finish line: Rounded shoulder (supragingival)
   - All preparations were performed using an ISO 173/018 diamond flat-end taper bur (TF13).
3. The prepared typodont was scanned using the **Dentsply Sirona Primescan** intraoral scanner.
4. The scan data was transferred to **Dentsply inLab CAD software** for designing the three-unit FPD. A single design was generated to maintain consistency between both groups.

Fabrication of Provisional FPDs

Group A – 3D-Printed Prostheses

- The digital design was exported in STL format and printed using **ACKURETTA SOL 3D printer**.
- The resin used was **ACKURETTA CURO (Ackuretta Technologies)**.
- The printing was performed in a standard orientation with manufacturer-recommended settings.
- After printing, prostheses were subjected to:
  - **Isopropyl alcohol wash**
  - **Post-curing** in a UV chamber for enhanced polymerization.
- A total of 15 FPDs were produced and finished using rotary instruments without altering the occlusal surfaces.

Group B – CAD/CAM-Milled Prostheses

- The same digital design was used to mill restorations from **pre-polymerized PMMA blocks** (UPSERA).
- Milling was performed using a 5-axis CAD/CAM milling unit.

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- Milled prostheses were polished using standard laboratory polishing techniques.

Flexural Strength Testing

- Each FPD was placed on a **universal testing machine ()**.
- The specimens were subjected to a **three-point bending test**:
  - Span length: 20 mm
  - Crosshead speed: 3 mm/min
  - Load applied at the center of the pontic until fracture occurred.
- The maximum load at fracture (in Newtons) was recorded.
- Flexural strength was calculated using the formula:

σ=3FL2bd2\sigma = \frac{3FL}{2bd^2}σ=2bd23FL

Where:
F = Maximum load (N)
L = Span length (mm)
b = Width of specimen (mm)
d= Depth (thickness) of specimen (mm)

Microhardness Testing

- After fracture, specimens were sectioned and **embedded in acrylic resin blocks**.
- The test surface was ground and polished using silicon carbide abrasive papers.
- Microhardness was measured using a **Reichert Vickers Microhardness Tester (Austria, Serial No. 363798)**.
- Test conditions:
  - Load: 50 grams
  - Dwell time: 15 seconds
- Indentations were made on the polished surface using a Vicke
- rs diamond indenter.
- The diagonals of the indentations were measured, and the Vickers Hardness Number (VHN) was automatically calculated by the software.
- The values were later converted to **Knoop Hardness Number (KHN)** using integrated software.

Table : comparison of Vickers micro hardnes among the study groups

Groups,	Mean	Std. Deviation	Tvalue	Pvalue
Group 1	17.3333	1.29099	-9.178	0.000*
Group 2	21.7333	1.33452		

- Independent t test p<0.05* significant
- The mean values of Vickers microhardness among the group1 and group 2 was 17.333 and 21.733 respectively and the difference was statistically significant with p=0.000*

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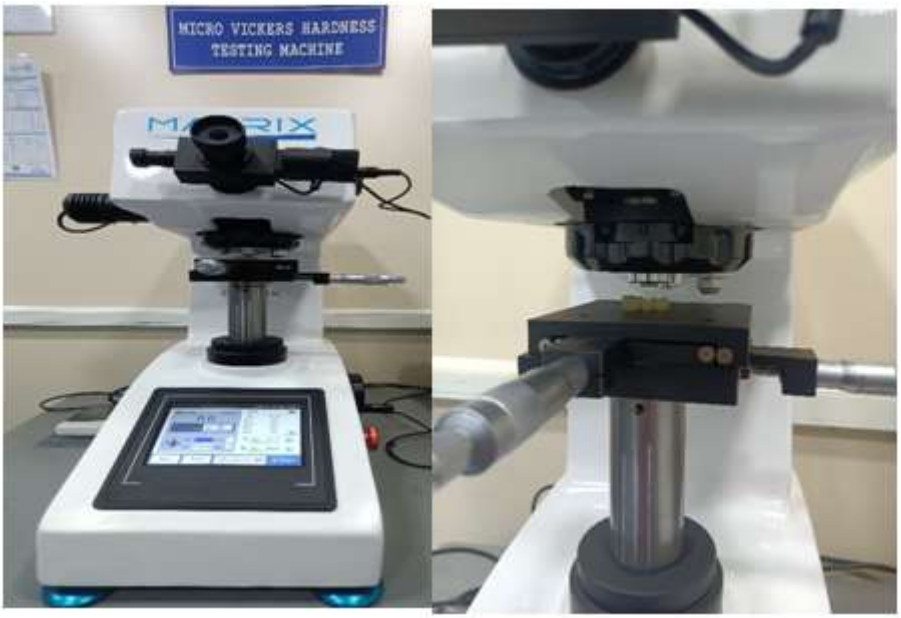


Figure 1:

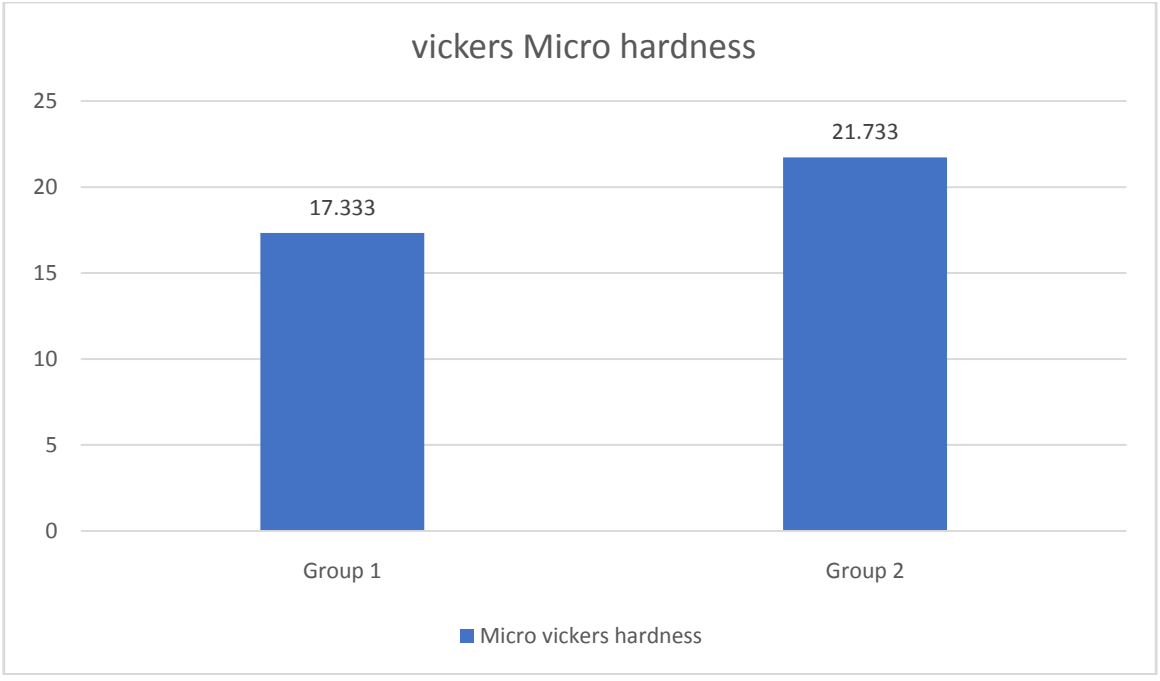
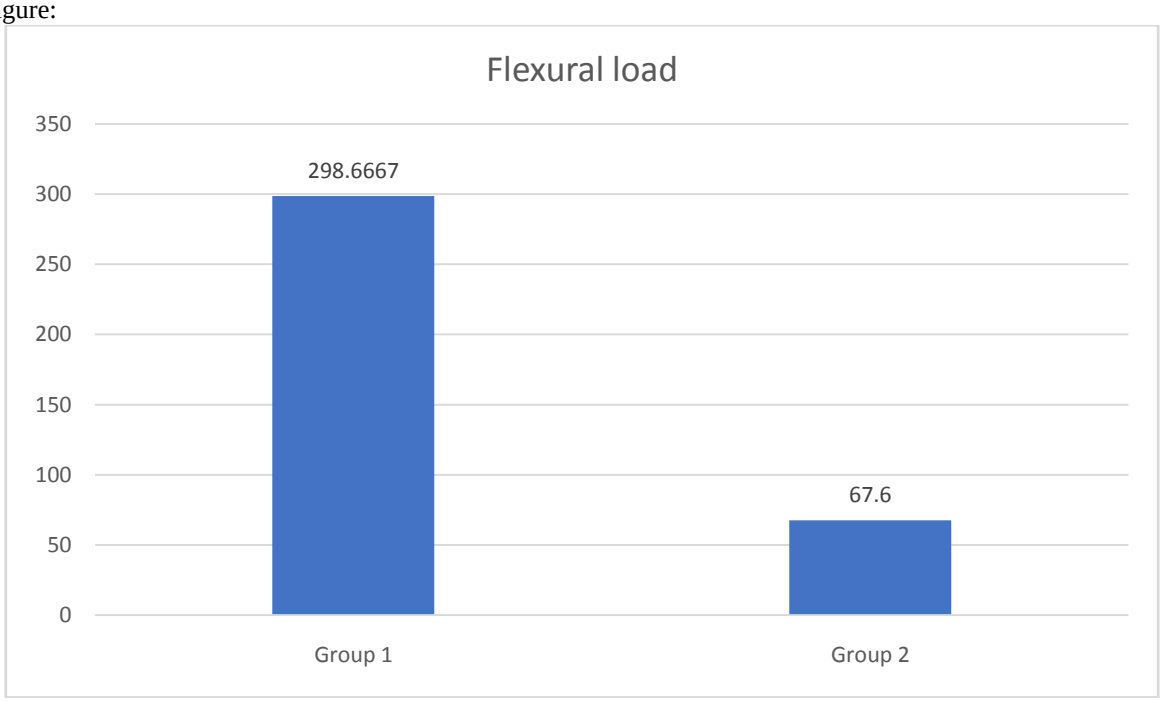


Table : comparison of flexural load among the study groups

Groups,	Mean	Std. Deviation	Tvalue	Pvalue
Group 1	298.6667	74.82042	11.824	0.000*
Group 2	67.6000	11.43803		

- Independent t test p<0.05* significant
- The mean values of flexural load among the group1 and group 2 was 298.6667 and 67.6000 respectively and the difference was statistically significant with p=0.000*

Figure:



Statistical Analysis

- The collected data were analyzed using **SPSS version [insert version, e.g., 25.0]**.
- Mean and standard deviation were calculated for each group.
- An **Independent t-test** was used to compare flexural strength and microhardness between groups.
- A p-value < 0.05 was considered statistically significant.

III. DISCUSSION

Provisional fixed dental prostheses (FDPs) are essential components of fixed prosthodontics and dental implantology. Provisional FDPs must meet the following requirements: pulpal protection, periodontal health, occlusal compatibility, maintaining tooth position, fracture protection, resistance to functional loads, resistance to removal forces, maintaining inter-abutment alignment, being easily contourable, color stable, and having sufficient translucency (Madhav, Digholkar, and Palaskar, 2016). [3]

Proper knowledge and understanding of material qualities are critical factors in determining the effectiveness and duration of a repair. Polymer-based materials, such as PMMA resin, are the primary choice for provisional restorations. The PMMA resin blocks for CAD-CAM systems have cross-linked structures, which improve mechanical qualities over traditional gold standard heat cured polymers. [4]

To address certain drawbacks of this technology, most notably material waste, additive manufacturing technology has recently been introduced as an alternative to subtractive techniques for the manufacture of long-term provisional restorations, due to its ability to manufacture unlimited objects due to manufacturing time, known as rapid prototyping (RP), which includes 3-D printing. It is utilized in prosthodontics to create physical models, surgical guides, extraoral maxillofacial prostheses, and, more recently, fixed prosthodontics for long-term provisional FDPs. This procedure has the advantage of not wasting any material. [14]

The present study investigated the flexural strength and microhardness of provisional FPDs fabricated by two different digital techniques: 3D printing and CAD/CAM milling. The results clearly showed that CAD/CAM-milled PMMA FPDs possess significantly greater flexural strength and microhardness compared to their 3D-printed counterparts

The milled group's flexural strength averaged 298.67 MPa, more than four times that of the 3D-printed group (67.60 MPa). This large difference is due to the industrial polymerization of PMMA blocks under controlled pressure and temperature settings, which produces a denser and more homogeneous microstructure. A study

examined CAD-CAM systems used in dentistry and advocated their application for provisionalization. Manufacturing under industrial settings enables high-density polymer-based restorations with favorable mechanical properties and biocompatibility (Rekow, 2006). [15]

Similarly, the milled group had greater Vickers microhardness values, indicating increased resistance to surface indentation and wear.

While 3D printing is still a useful and effective approach for short-term provisionals or diagnostic mock-ups, its inferior mechanical qualities indicate that it should be used sparingly in circumstances demanding long-term durability and occlusal load resistance.

Material composition, printer type, and post-curing methods all have an impact on the performance of 3D-printed items. Further research comparing different 3D printing resins and optimizing post-processing techniques may help to close this mechanical gap.

The current study assessed and contrasted two commonly used fabrication procedures for provisional FDPs: 3D printing with light-curable resins and CAD/CAM milling using PMMA blocks. The study found that milled provisional FDPs outperformed 3D-printed counterparts in terms of flexural strength and Vickers microhardness.

Alageel et al. [16]investigated the flexural strength, trueness, and surface properties of 3D-printed interim restorative materials produced using various printing techniques. Flexural strength, microhardness, and surface roughness vary according to the material, printing procedure, and orientation. Aging has an impact on dependability and mechanical properties, with some materials exhibiting changes following simulated brushing and thermocycling. Dos et al. [17]investigated the binding strength of 3D-printed provisional crowns using three different provisional cements before to and following thermal aging. Glass ionomer cement has the strongest initial bond strength, and all cement types experience a decline in adhesion force with age. The findings highlight the need of using adequate temporary cements for long-term stability in 3D-printed restorations.

Madhav et al. [18]investigated the flexural strength and microhardness of provisional restorations made using fast prototyping (3D printing), CAD-CAM machining, and conventional procedures. The findings revealed that CAD-CAM-fabricated restorations had the best flexural strength, whereas 3D-printed restorations had the highest microhardness. This shows that, while 3D printing improves surface hardness, CAD-CAM repairs may be more resilient to functional pressures.

Pantea et al. [19] examined the compressive and flexural strength of 3D-printed with conventional interim prosthetic resins. The study discovered that 3D-printed materials exhibited higher elastic moduli and bending strength than conventional resins, indicating superior mechanical endurance. This contributes to the expanding use of 3D printed materials in dentistry for long-term temporary restorations.

Park et al. [4] investigated the flexural strength of three-unit fixed dental prosthesis made utilizing various 3D printing processes, such as digital light processing (DLP), stereolithography (SLA), and fused deposition modeling (FDM). DLP and SLA restorations exhibited much greater flexural strength than traditional restorations, indicating their viability for provisional prosthesis.

Overall, the results show that 3D-printed provisional restorations have excellent mechanical qualities, especially in terms of surface hardness and elasticity. However, CAD-CAM restorations still have higher flexural strength, making them ideal for high-load applications. The findings highlight the importance of careful material selection and post-processing to ensure the lifetime and performance of 3D-printed dental restorations.

The use of 3D printing in dentistry has altered the production process for provisional and permanent restorations. The included research demonstrate the benefits and drawbacks of 3D-printed provisional materials when compared to traditional and CAD-CAM-milled alternatives.

Alageel et al. [16]and Alzahrani et al. [20] emphasize that 3D-printed resins exhibit superior hardness and wear resistance compared to conventional provisional materials. Studies like Park et al. and Madhav et al. confirm that digital light processing (DLP) and stereolithography (SLA) produce restorations with higher flexural strength than traditional counterparts. However, Pantea et al. and Dos et al. highlight variability in adhesion and bond strength, which may impact long-term clinical performance.

The role of digital workflows is evident in studies like Jiang et al. and Spagnuolo et al., [21]which discuss advancements in DLP technology that enhance precision and efficiency in fabricating dental prostheses. These studies suggest that improvements in adhesion and demolding techniques, such as porous build platforms, contribute to better manufacturing outcomes. Lakkala et al. [22] reinforce the idea that stereolithography (SLA) provides high precision,

making it well-suited for customized dental applications, particularly in cases requiring detailed

Spagnuolo et al. and Wang et al. [23] examine the environmental and material efficiency benefits of 3D printing when compared to subtractive processes such as milling. Milling, despite its great precision, generates significant material waste, whereas 3D printing allows for layer-by-layer manufacturing, decreasing excess material use. Nonetheless, Wang et al. note that current DLP systems face speed and scalability limits, particularly when high-volume output is required.

While Park et al. [4] found that 3D-printed restorations have appropriate mechanical characteristics for interim applications, questions about their long-term durability remain. Dos et al.[17] and Alzahrani et al. propose additional tuning of resin compositions to improve fracture resistance and bond stability in oral settings. Future studies should concentrate on hybrid resin formulas that combine the mechanical robustness of milled restorations with the efficiency and adaptability of 3D-printed materials.

Flexural Strength

Group B (milled) has much higher flexural strength than Group A (3D-printed). This finding is consistent with earlier investigations (e.g., Alt et al., 2011; Karaokutan et al., 2015), which have repeatedly shown that CAD/CAM-fabricated restorations are more resistant to fracture. The improved performance of milled PMMA is attributed to industrial polymerization under high pressure and temperature, which results in a more uniform and dense microstructure, eliminating voids and residual monomer content that might impair mechanical integrity.

3D-printed resins, on the other hand, are manufactured layer by layer, making them more prone to interlayer delamination and inadequate polymerization, both of which can diminish mechanical strength. Even though 3D printing enables rapid fabrication and cost-effective production, its lesser strength makes it unsuitable for long-term provisional usage, particularly in high-stress locations or for patients with parafunctional habits such as bruxism.

Microhardness

Surface microhardness is another important criterion that determines the wear resistance and lifespan of restorations. In this investigation, the milled group showed much greater microhardness values than the 3D-printed group. This could be ascribed to the denser molecular structure and higher conversion rate of PMMA blocks. Higher surface hardness also means higher wear resistance, polishing retention, and lower bacterial adhesion, all of which are essential for maintaining hygiene and gingival health.

The Vickers microhardness values observed in the 3D-printed group, while lower, were nonetheless clinically acceptable for short-term uses. However, this limits their application in cases of protracted temporization, particularly in posterior regions with larger masticatory forces.

Clinical Implications

Clinical considerations for material selection include the duration of usage, location of the restoration, and patient-specific characteristics. While 3D-printed provisionals may be suitable for short-term temporization or cosmetic mock-ups, CAD/CAM-milled restorations should be used in situations needing high strength, long-term use, or heavy occlusal stress.

Limitations and Future Directions

This study's shortcomings include its in vitro nature, which does not fully duplicate intraoral circumstances such as moisture, pH changes, or dynamic loading. To corroborate these findings, additional study could include aging simulations, wear behaviour, and clinical trials. Furthermore, research into newer 3D-printable materials with improved mechanical performance could help bridge the gap between additive and subtractive processes.

IV. CONCLUSION

Within the limits of this in vitro study, CAD/CAM-milled PMMA provisional FPDs had much greater flexural strength and microhardness than those made using 3D-printed resin. Milled interim restorations may be desirable in situations when long-term strength and wear resistance are critical.

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