DOI: 10.7860/JCDR/2025/73967.20647

Original Article

Dentistry Section

Comparative Analysis of 3D Printing, Computer Aided Design and Milling and Conventional Fabrication Techniques on Fracture Resistance of Interim Restorations: A Systematic Review and Meta-analysis

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ABSTRACT

Introduction: The fracture resistance of interim restorative materials is important for success of dental restorations. Various fabrication methods have been employed to create provisional restorative materials, but impact of these methods on fracture resistance remains unclear. Understanding the influence of different fabrication techniques of interim restorative materials on fracture resistance is essential for optimising clinical outcomes, patient satisfaction, and overall dental treatment success.

Aim: To compare the effect of different fabrication techniques on fracture resistance of interim restorations.

Materials and Methods: A systematic search was conducted in electronic databases, which included PubMed, Scopus, and Corrections: Web of Science (WoS), to identify relevant studies published. Studies were included if they met the following criteria: Investigate the fracture resistance of provisional restorative materials, compare different fabrication techniques, published in English and peer-reviewed articles. Studies were excluded if they do not meet these criteria or are not available in full text. The quality of included studies was assessed using a validated tool modified Consolidated Standards of Reporting Trials (CONSORT) checklist. A meta-analysis was performed to quantitatively analyse the effect of different fabrication techniques on the fracture resistance of provisional restorative materials. Subgroup analyses and sensitivity analyses was conducted if necessary.

Results: The initial search yielded 254 potential articles. After removing duplicates and conducting a thorough screening of titles, abstracts, and full texts, 17 articles met the inclusion criteria for the study which were included for qualitative analysis. Data were extracted regarding the authors' details, the journals and years of publication, different fabrication methods and materials and evaluation of fracture resistance. The result revealed that there was no statistically significant difference for fracture resistance between Computer Aided Design and Computer Aided Manufacturing (CAD-CAM) and 3D-printed interim restorations {Mean difference=50.72 (95% CI=143.55, 244.99)} whereas there was statistically significant difference between CAD-CAM and conventional restorations {mean difference=282.58 (-411.59, -153.47)} and 3D printed and conventional interim restorations {Mean difference=169.75 (95% CI=353.68, 14.17)}. The p-value is not significant but there is difference seen.

Conclusion: Polymethyl Methacrylate (PMMA) CAD/CAM milled interim restorations demonstrated the highest fracture resistance among the groups compared in the study. This finding highlights the superior durability and strength of CAD/CAM milling technology, particularly when using PMMA as the material for fabricating provisional restorations. The precise and controlled nature of the milling process ensures a strong, reliable restoration with high fracture resistance, making it the ideal choice for many clinical situations. A 3D-printing was shown to be a stronger and more reliable manufacturing method for interim restorations when compared to traditional conventional techniques (such as indirect methods). Although 3D-printed restorations exhibited lower fracture resistance than CAD/CAM milled restorations, they still offer a significant advantage over conventional techniques in terms of strength and reliability. This suggests that 3D-printing can be a viable alternative, especially when CAD/CAM milling is not available or feasible.

Keywords: Additive manufacturing, Dental prosthesis, Mechanical properties, Provisional fixed dental prosthesis, Rapid prototyping, Temporary crowns

INTRODUCTION

Interim restorations are an integral and unavoidable part of fixed prosthodontics. It is applicable right from the time of tooth preparation till the definitive restorations are fabricated. The provisional restorations have many functions like pulpal protection, occlusal stabilisation and masticatory function. They should be able to function under occlusal forces and also able to withstand fluctuations in oral temperature and saturated humidity for a reasonable period of time [1-4].

Currently, the materials used for provisionalisation comprise of two popular groups, methacrylates like Polymethyl Methacrylate (PMMA), Polyethyl/Butyl Methacrylate (PEMA) and other combinations of methacrylate and dimethacrylate resins. Other materials like Bisphenol A-Glycidyl Dimethacrylate (Bis-GMA) and Urethane Dimethacrylate (UDMA) and visible light polymerised resin are also used [5].

The various techniques for fabricating provisional restorations are direct method wherein restorations are fabricated directly in the patient's mouth, indirect method and indirect-direct method [4]. Most commonly conventional method is used because of low cost and accessibility, however, there are few drawbacks like material shrinkage, colour instability etc., with this method and limit its application.

Advancements in digital technology, such as machining or subtractive manufacturing of pre-processed PMMA disks, has provided provisional materials with improved properties [5,6]. CAD-CAM based interim restorative materials have highly cross-linked structures. The changes in the structural properties provide increased strength, durability and reduced residual monomer content. Despite improved mechanical properties, milling procedure limits the use due to its cost [2,3,7,8]. An alternative to milling is 3D printing method for fabricating temporary restorations. Advantages include low cost and reduced fabrication time. Although, they offer advantages over milled ones but the mechanical properties are not yet investigated sufficiently [4,9].

Despite the innovations on various fabrication techniques and the materials used for interim restorations, there is very limited knowledge regarding the effect of these fabrication methods on fracture resistance of interim restorations. Hence, this systematic review focuses on comparison and effect of different fabrication techniques on fracture resistance of interim restorations.

MATERIALS AND METHODS

Protocol and registration: The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [10].

Eligibility criteria: The studies were selected based on the PICOS framework, which stands for:

PICOS

P: Participants: Provisional materials;

I: Intervention: Different fabrication methods;

C: Comparison: Conventional and CAD-CAM, Conventional and 3D, CAD-CAM and 3D, conventional, CAD-CAM and 3D;

O: Outcome: Fracture resistance;

S: Study design: In-vitro studies.

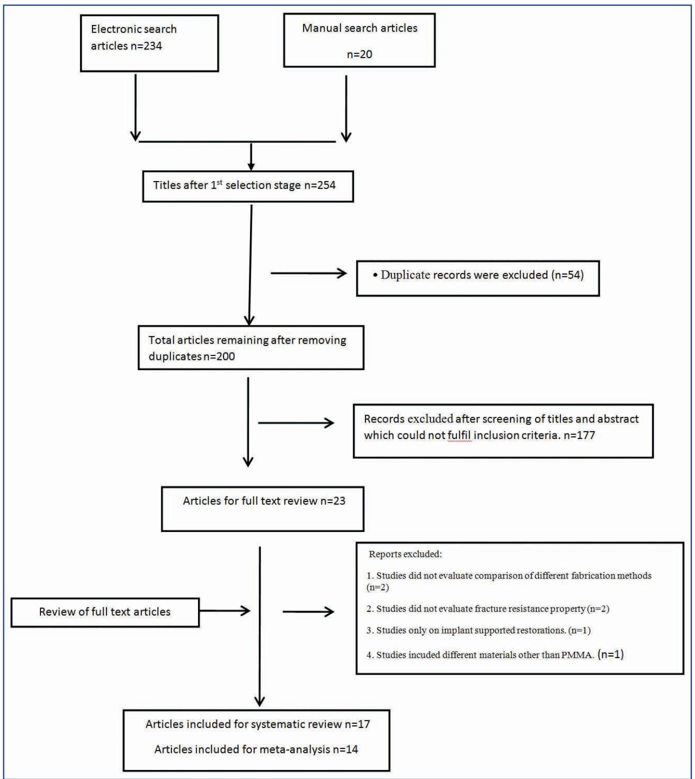
Inclusion criteria: Original in-vitro study and full text article;

- Study on comparisons of CAD-CAM and\or conventional and\ or 3D fabrication methods of provisional restorations;
- Studies which included PMMA material for CAD-CAM and conventional methods;
- Studies on direct or indirect method of fabrication for conventional method only;
- Study specimens which included blocks, crowns or FPDs;
- Studies which included evaluation of fracture resistance;
- SI unit of fracture resistance was in N (Newtons).
- Studies which measured fracture resistance incorporating other variables like thermocycling, cyclic loading and storage time;
- Studies between different manufacturers of provisional materials.

Exclusion criteria: Review articles, incomplete studies, case reports, in-vivo studies were excluded; Other mechanical properties in the same study; SI unit other than N; Studies without units.

Information sources and search strategy: The literature search was conducted across multiple reputable databases to capture a broad range of relevant studies in PubMed, Scopus, Web of Science, to identify relevant articles from January 2000 to March 2022. The search strategy involved a combination of Medical Subject Headings (MeSH) terms and entry terms related to the topic with a sensitive search strategy as shown in [Table/Fig-1,2]. These keywords were used with Boolean operators AND, OR, and NOT. The retrieved results were cross checked to eliminate duplicates.

Selection of articles: Two independent review authors (BSP and AAK) screened the titles and abstracts of articles based on predefined inclusion criteria. If there was disagreement between the two reviewers, the article was set aside for further evaluation in the next stage. Articles that were either included or uncertain from the first stage underwent full-text evaluation by the same two independent reviewers (BSP and AAK). If the two reviewers disagreed on whether an article should be included or excluded, a third reviewer was involved to resolve the disagreement. Two additional review authors (AAK and CVP) assessed the reference lists of all articles selected in the second stage. They then reviewed the full texts for any potentially relevant studies identified through this process.



[Table/Fig-1]: Information sources and search strategy.

Population	#1	Dental restoration OR “temporary dental restoration” OR Dental Prosthesis (MeSH). OR “provisional dental restoration” OR “Provisional crown” OR “interim resin” OR “interim fixed partial denture (MeSH)”
Intervention	#2	“3D print” OR “Stereolithography” OR “Additive Manufacturing” AND “Digital technology” OR “Stereolithography” OR “Rapid prototyping”
Comparisons	#3	“Computer-Assisted manufacturing” OR “Computer-Assisted Milling” AND “3D Printing” OR “CAD-CAM” AND “Conventional technique” AND “Additive Manufacturing”
Outcomes	#4	“Mechanical property” OR “mechanical behavior” OR “fracture resistance” OR “fracture toughness”
Search combination		#1 AND #2 AND #3 AND #4

[Table/Fig-2]: Search strategy.

Data extraction process: A data extraction table was created in Microsoft Excel, which is a widely used tool for organising and analysing data. The data extraction table included the following categories of information: publication details like authors and year of publication, type of study, sample size (N), specimen geometry, method of fabrication of interim prosthesis and chemical composition of provisional materials.

Risk of bias assessment: The Modified CONSORT scale for in-vitro studies given by Faggion CM [11], and previous systematic review [12,13]. was used to assess the quality of the included studies.

Criteria to evaluate risk of bias assessment were following:

1. Structured abstract
2a. Scientific background and rationale
2b. Objectives and/or hypothesis
3. Intervention of each group
4. Outcomes

5. Sample size determination
6. Randomisation: Sequence generation
7. Allocation concealment mechanism
8. Implementation
9. Blinding
10. Statistical method
11. Outcome and estimation
12. Limitation
13. Funding
14. Protocol

The quality of reporting was evaluated based on a set of 14 checklist criteria, which were used to assess whether each study properly reported essential information. For each criterion, the reviewers made a judgment about whether the item was correctly reported. The judgment was based on a pre-specified question: "Was the item correctly reported?" If the item was reported correctly, the judgment was "yes" (reported). If the item was not reported or was reported inadequately, the judgment was "no" (not reported).

Two authors independently conducted the assessment of each article. This independent evaluation helps reduce the risk of bias and ensures that the judgment was consistent. If there was any uncertainty or disagreement between the two reviewers regarding the reporting of a particular criterion, they resolved it through discussion.

RESULTS

Identification and selection: This review focussed on the fracture resistance of resins used for fabricating provisional restorations via different techniques (3D printing, CAD/CAM milling, and conventional methods). A primary search was conducted across selected electronic databases, complemented by a manual search. In total, 254 titles were identified from the initial search. After reviewing the titles, 54 articles were removed, leaving 200 articles for further review. The titles and abstracts of these 200 articles were assessed to determine whether they met the pre-established inclusion and exclusion criteria. As a result, 177 articles were excluded because they did not meet the criteria. The full texts of the remaining 23 articles were thoroughly reviewed to assess their relevance to the research question. Additionally, the reference lists of these 23 articles were manually searched for any other potentially relevant studies. However, no additional articles were found through this secondary search. Out of the 23 articles, six were excluded because they focused on comparing other properties of the resins (not mechanical properties) or compared provisional 3D-printed resins with definitive restorative materials (which were outside the scope of the review).

Thus, 17 articles [1-7,14-23] were finally included in this systematic review for qualitative analysis and 14 articles were included for quantitative analysis [Table/Fig-1].

Study characteristics: All the included articles were in-vitro studies. Characteristics of included studies are presented in [Table/Fig-3].

Author and year	Type of study	N	Method of fabrication	Chemical composition of provisional material	Specimen geometry	Author's conclusion on fracture resistance
Conventional vs CAD-CAM						
Penate L et al., 2015 [1]	In-vitro	10	Direct conventional CAD-CAM	a. Bbisacryl resin b. PMMA reinforced with glass fibres c. PMMA PMMA	FPD	No signicant difference between reinforced conventinal and CAD-CAM
Rayyan MM et al., 2015 [2]	In-vitro	(not clearly mentioned)	Direct conventionl CAD-CAM	a MMA/PMMA b Bisacryl c Acetyl copolymer PMMA	Crowns	CAD-CAM > Conventional
Karaokutan I et al., 2015 [3]	In-vitro	10	Direct conventionl CAD-CAM	a PMMA b Bisacryl c Polyurethane methacrylate d Bisacryl composite highly cross linked methylmethacrylate	Crowns	CAD-CAM > Conventioanl composite based > conventional PMMA
Abdulla AO et al., 2018 [7]	In-vitro	10	Direct conventional CAD-CAM	Acrytemp Vita Artbloc temp PMMA	Crowns	Artbloc > PMMA > Vita CAD-CAM > conventional
Pop DA MR et al., 2018 [14]	In-vitro	5	Conventional indirect CAD-CAM	PMMA PMMA	FPD	CAD-CAM > Conventional
Reeponmaha T 2019 [15]	In-vitro	8	Conventionl direct CAD-CAM	PMMA Bisacryl PMMA	Crowns	Bisaryly > CAD-CAM PMMA
Sari T et al., 2020 [16]	In-vitro	90	Conventional direct CAD-CAM	Bisacrylate PMMA	Crowns	Conventional > CAD-CAM but difference is not significant
Ahmadzadeh A and Haghighizadeh MH 2021 [17]	In-vitro	10	Conventional indirect CAD-CAM	PMMA Bisacryl composite PMMA	FPD	CAD-CAM > bisacryl composite > PMMA conventional
Waleed S 2022 [18]	In-vitro	6	Conventional direct CAD-CAM	Bisacryl composite PMMA Acrylate polymer	FPD	CAD-CAM PMMA > CAD-CAM acrylate > conventional
CAD-CAM vs 3D						
Ibrahim A 2020 [19]	In-vitro	8	3D CAD-CAM	Microfilled acrylic resin PMMA	Crowns	3 D > CAD-CAM
Abad-Coronel C et al., 2021 [4]	In-vitro	20	3D CAD-CAM	Light cure microhybrid resin PMMA	FPD	CAD-CAM > 3D
CAD-CAM vs 3D vs Conventional						
Reeponmaha T et al., 2020 [20]	In-vitro	10	CAD-CAM 3D Conventional direct	PMMA Light polymerised bisacrylate PMMA Bisacryl	Crowns	Conevntional bisacryl > CAD-CAM > 3D > conventional PMMA
Al Halabi MN et al., 2020 [21]	In-vitro	10	CAD-CAM 3D Conventional direct	PMMA Glycidyl carbamate light cure Composite Celluloid	Crowns	CAD-CAM > 3D > conventional

Othman A et al., 2021 [22]	In-vitro	7	CAD-CAM 3D Conventional direct	PMMA Light polymerised Bisacryl	FPD	CAD-CAM > conventional >3D
Tasin S and Ismatullaev A 2022 [23]	In-vitro	30	CAD-CAM 3D Conventional direct	PMMA Composire resin PMMA Bisacryl	Blocks	CAD-CAM and 3D > bisacryl > PMMA
Henderson JY et al., 2022 [5]	In-vitro	15	CAD-CAM 3D Conventional direct	PMMA Bisacryl Bisacryl	FPD	CAD-CAM > 3D > conventional
Reymus M et al., 2019 [6]	In-vitro		CAD-CAM 3D Conventional direct	PMMA Methylmethacrylates Bisacryl methacrylate	FPD	CAD-CAM > 3D > conventional

[Table/Fig-3]: Showing the studies included in the review [1-7,14-23].

Risk of bias of the 17 studies and 14 criteria are mentioned in the [Table/Fig-4]. All the included studies correctly reported criteria 3: intervention of each group, criteria 4: outcomes, criteria 7: allocation concealment mechanism, criteria 9: blinding, criteria 11: outcome and estimation, criteria 14: protocol.

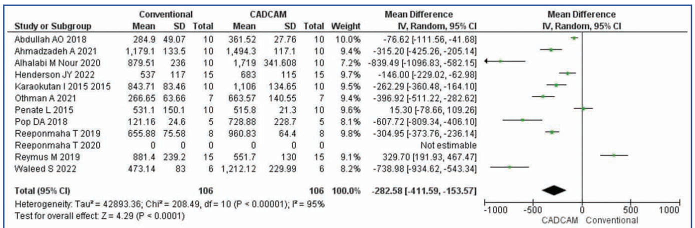
Item	Penate L	Rayyan MM	Karaokutan I	Abdullah AO	Pop DA MR	Reeponmaha T	Sari T	Ahmadzadeh A	Waleed S	Ibrahim A	Abad- Coronel C	Reeponmaha T	Al Halabi MN	Othman A	Tasin S	Henderson JY	Reymus M
1	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
2a	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2b	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6	No	Yes	Yes	No	No	Yes	Yes	No	Yes	No	No	Yes	No	No	No	Yes	Yes
7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes	Yes
9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
10	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes
11	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
12	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
13	Yes	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes
14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

1. Structured abstract, 2. a Scientific Background and rationale, 2. b Objectives and/or hypothesis, 3 Intervention of each group 4. Outcomes, 5. Sample size determination, 6. Randomisation: Sequence generation, 7. Allocation Concealment mechanism, 8. Implementation, 9. Blinding, 10. Statistical Method, 11. Outcome and Estimation, 12. Limitation, 13. Funding, 14. Protocol

[Table/Fig-4]: Risk of bias assessment.

Quantitative analysis: The meta-analysis was performed using RevMan Software version 5.4. A meta-analysis for the included articles [1,3-7,14,15,17-22]. was done after extracting the data of mean fracture resistance of temporary restorations. Rayyan MM et al., Sari T et al., Tasın S and Ismatullaev A [2,16,23]. were excluded from quantitative analysis as the data of different domains couldn't be compared. Heterogeneity in meta-analysis was estimated using Chi-square test and I I_2 test. An I_2 value >50% was considered as substantial heterogeneity, and random effect model was employed for meta-analysis.

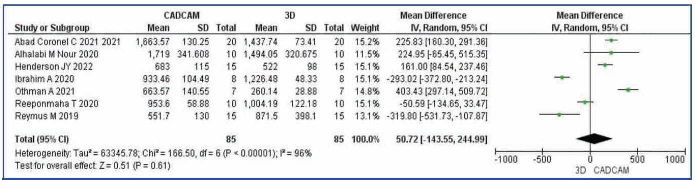
A meta-analysis was performed to compare the fracture resistance of temporary crowns processed using Conventional technique and CAD/CAM technique [Table/Fig-5]. In this meta-analysis, about 12 studies [1,3,5-7,14,15,17,18,20-22]. were included and it was observed that the heterogeneity was substantial with I_2 value of 95%. Therefore, random effect model was employed. The result of this analysis yielded statistically significant result showing that the CAD/CAM temporary restorations were superior {Mean difference=282.58 (-411.59, -153.47)}. to conventional crowns with regard to fracture resistance.



[Table/Fig-5]: Comparison of conventional vs CAD/CAM fabrication technique on fracture resistance of interim restorations.

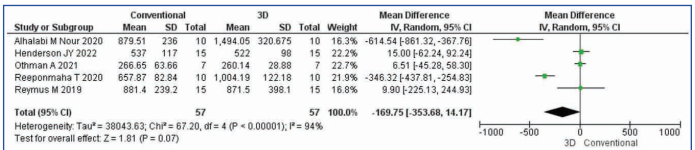
In this meta-analysis, seven studies [4-6,19-22] comparing fracture resistance between CAD/CAM and 3D temporary crowns were included [Table/Fig-6]. Considering the high heterogeneity of 96%, the random effect model was employed. The result revealed that there was no statistically significant difference {Mean difference=50.72 (95% CI=143.55, 244.99)}. of fracture resistance was observed between CAD-CAM and 3D temporary crowns.

This meta-analysis comparing the fracture resistance of Conventional and 3D temporary crowns included five studies [Table/Fig-7] [5,6,20-22]. The 3D temporary crowns were showed more fracture



[Table/Fig-6]: Comparison of CAD/CAM vs 3D printing fabrication technique on fracture resistance of interim restorations.

resistance {Mean difference=169.75 (95% CI= 353.68,14.17)} than the conventional temporary crowns. The random effect model was employed because of substantial heterogeneity of 94%.



[Table/Fig-7]: Comparison of conventional vs 3D printing fabrication technique on fracture resistance of interim restorations.

DISCUSSION

With the advent of digital technology, there has been a revolution in the treatment provided for fixed prostheses [24]. The previous systematic reviews have compared the mechanical properties of provisional materials but there is no sufficient literature which states the effect of different fabrication techniques on the fracture resistance of interim materials [25-27]. Hence, this systematic review and meta-analysis is one of its kind where the fracture strength of the conventional, CAD/CAM milled and/or 3D printing fabrication methods for provisional resins have been compared. All in-vitro studies are included [1-7,11-20]. The findings of the studies reveal that the fracture strength is affected by the method of fabrication and composition of the materials. The fracture strength of conventional, CAD/CAM milled and 3D printed interim restorations will be discussed.

Conventional methyl methacrylate resins have low molecular weight, are linear and monofunctional [28] and exhibit decreased rigidity and strength [29]. Conventional provisional resin materials when mixed either by manual or with automixing tips show incorporation of air bubbles and porosities which leads to absorption of water into the polymer network, which hampers the mechanical properties of the material [2,7,30].

The 3D printed materials are fabricated by a layering technique wherein the layers are deposited one over the other [19]. As the layers are deposited a concentrated beam is focused and polymerises the layer by layer forming a chemical bond between layers. The layers may either be deposited vertically or horizontally. In the vertical deposition, the layers are perpendicular to the direction of load applied whereas in the horizontal, the layers are parallel to the load [25,31,32].

The technique, orientation and thickness of each layer during printing affects the mechanical properties [19,33]. Ibrahim A et al., and Tahayeri A et al., stated that lesser the thickness of each layer during printing, the better it is polymerised and better will be the mechanical properties of these materials [19,34]. Post fabrication, 3D-printed materials are cured, which reduces the amount of residual monomer and increases the degree of conversion [35,36]. This difference in composition, high level of construction as well as the chemical bond between layers can be the reason for their superior wear resistance properties.

The CAD-CAM PMMA blocks are more homogenous, have less solubility and water sorption as they are industrially polymerised under optimum conditions [37-39]. Prior to utilisation, the blocks are kept under air for post polymerisation which helps in releasing excess monomer from the blocks [40].

In studies by Karaokutan I et al., and Alp G et al., compared the fracture resistance of PMMA block crowns fabricated using CAD/CAM technology with crowns made using indirect technique with PMMA and Protemp 4 and they stated that the PMMA blocks had better fracture resistance compared to the indirect techniques [3,41]. Pop DA et al., conducted a study on comparison of the fracture resistance of provisional restorations of 3-unit FPDs fabricated by indirect techniques and CAD-CAM techniques, the study concluded that fracture resistance in CAD/CAM technology was significantly higher than that in the indirect method [14]. This suggests that CAD/CAM techniques may provide stronger and more durable restorations compared to traditional methods, likely due to the precision and consistency of the CAD/CAM milling process. Alt V et al., reported that directly fabricated PMMA restorations had lower fracture resistance than those fabricated using CAD/CAM PMMA blocks. This finding suggests that CAD/CAM technology, which allows for more precise fabrication, results in stronger provisional restorations when using PMMA, compared to direct methods that might not offer the same level of accuracy or control over material properties [42].

Abad-Coronel C et al., found a significant difference in fracture resistance between 3D printed and CAD/CAM milled interim restorations, with the CAD/CAM milled restorations showing greater resistance to fracture [4]. Specifically, the milled restorations were more resilient to damage and showed sharper fractures under microscopic examination, while the 3D printed restorations exhibited more irregular fracture lines with areas of tearing. This suggests that there is better resilience of milled crowns to applied load and catastrophic failure [43].

Limitation(s)

The review focused only on fracture resistance as the mechanical property of interest. This limits the applicability of the findings since other important mechanical properties (such as wear resistance, tensile strength, etc.,) were not considered. The review only included in-vitro studies, which means the findings are based on laboratory conditions rather than clinical (in-vivo) environments. While in-vitro studies are useful for initial exploration of material properties, they do not fully replicate the complexities of the oral cavity, such as masticatory forces, temperature variations, and moisture. Many of the included studies had small sample sizes, which could affect the reliability and statistical power of the results. Given these limitations (focus on fracture resistance, in-vitro studies, and small sample sizes), the review's results should be cautiously interpreted. The in-vitro study design cannot fully replicate the oral environment, where materials are subject to dynamic conditions like chewing forces, temperature changes, and exposure to saliva. However, in-vitro studies serve as preliminary models that provide useful information before moving on to more complex in-vivo studies. A risk of bias was noted, particularly regarding randomisation sequence generation. In 50% of the studies, this was not reported, which raises concerns about the methodological rigor of those studies. Randomisation is important to minimise bias and ensure that the results are reliable and not skewed by confounding factors.

CONCLUSION(S)

This systematic review and meta-analysis concluded that PMMA CAD/CAM milled three-unit interim restorations demonstrated the highest fracture resistance among the different fabrication methods tested. The 3-D printed three-unit interim restorations may be suitable for cases with lower chewing loads and in patients without parafunctional habits.

REFERENCES

[1] Penate L, Basilio J, Roig M, Mercade M. Comparative study of interim materials for direct fixed dental prostheses and their fabrication with CAD/CAM technique. J Prosthet Dent. 2015;114:248-53.
[2] Rayyan MM, Aboushelib M, Sayed NM, Ibrahim A, Jimbo R. Comparison of interim restorations fabricated by CAD/CAM with those fabricated manually. JProsthet Dent. 2015;114(3):414-19.
[3] Karaokutan I, Sayin G, Kara O. In-vitro study of fracture strength of provisional crown materials. J Adv Prosthodont. 2015;7(1):27-31.
[4] Abad-Coronel C, Carrera E, Mena Córdova N, Fajardo JI, Aliaga P. Comparative analysis of fracture resistance between CAD/CAM materials for interim fixed prosthesis. Materials (Basel). 2021;14(24):7791.
[5] Henderson JY, Korioth TV, Tantbirojn D, Versluis A. Failure load of milled, 3D-printed, and conventional chairside-dispensed interim 3-unit fixed dental prostheses. J Prosthet Dent. 2022;127:275.e1-275.e7.
[6] Reymus M, Fabritius R, Kebler A, Hickel R, Edelhoff D, Stawarczyk B. Fracture load of 3D-printed fixed dental pros-theses compared with milled and conventionally fabricated ones: The impact of resin material, build direction, post-curing, and artificial aging-an in-vitro study. Clin Oral Investig. 2020;24:701-10.
[7] Abdullah AO, Pollington S, Liu Y. Comparison between direct chairside and digitally fabricated temporary crowns. Dent Mater J. 2018;37(6):957-63.
[8] Dureja I, Yadav B, Malhotra P, Dabas N, Bhargava A, Pahwa R. A comparative evaluation of vertical marginal fit of provisional crowns fabricated by computer-aided design/computer-aided manufacturing technique and direct (intraoral technique) and flexural strength of the materials: An in-vitro study. J Indian Prosthodont Soc. 2018;18(4):314-20.
[9] Kumar R, Jayakrishnan S, Ramakrishnan H, Mahadevan V. Evaluation of the flexural strength of CAD/CAM milled polymethylmethacrylate and rapid prototype 3D printed resin for long term provisional restorations. Acta Scientific Dental Sciences. 2022;6(4):88-94.
[10] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.
[11] Faggion CM. Guidelines for reporting pre-clinical in-vitro studies on dental materials. J Evid Based Dent Pract. 2012;12:182-89.
[12] Pereira GK, Venturini AB, Silvestri T, Dapieve KS, Montagner AF, Soares FZ. Low temperatures degradation of Y TZP ceramics: A systematic review and meta-analysis. J Mech Behav Biomed Mater. 2015;55:151-63.
[13] Rodrigues CDS, Aurélio IL, Kaizer MDR, Zhang Y, May LG. Do thermal treatments affect the mechanical behavior of porcelain-veneered zirconia? A systematic review and meta-analysis. Dent Mater. 2019;35(5):807-17.
[14] Pop DA MR, Marsavina L, Hosszu T, Rotar R, Goguta L, Duma VF, et al. Fracture resistance of CAD/CAM versus traditional interim fixed dental prostheses. Materiale Plastice. 2018;55(3):361-63.
[15] Reeponmaha T, Angwaravong O, Angwarawong T. Fracture resistance of provisional crowns fabricated with CAD/CAM process and conventional process after aging in simulated oral condition. 2019:923-31. Available from: https://app.gs.kku.ac.th/gs/th/publicationfile/item/20th-ngrc-2019/MMO18/MMO18.pdf.
[16] Sari T, Usumez A, Strasser T, Sahinbas A, Rosentritt M. Temporary materials: Comparison of in-vivo and in-vitro performance. Clin Oral Investig. 2020;24(11):4061-68.
[17] Ahmadzadeh A, Haghighizadeh MH. Comparing fracture resistance of provisional restorations of 3-unit fixed partial dentures: An in-vitro study of CAD/CAM versus indirect technique. Indian Journal of Forensic Medicine & Toxicology. 2021;2:2009-16.

[18] Waleed S, Alsmail, Abbas M, Dawood L. Fracture resistance of different types of long term provisional fixed dental prostheses (In-vitro study). IOSR Journal of Dental and Medical Sciences. 2021;21:28-32.
[19] Ibrahim A, Shehawy DE, El-Naggar G. Fracture resistance of interim restoration constructed by 3D printing versus CAD/CAM technique (in-vitro study). Ain Shams Dent J. 2020;23:13-20.
[20] Reeponmaha T, Angwaravong O, Angwarawong T. Comparison of fracture strength after thermo-mechanical aging between provisional crowns made with CAD/CAM and conventional method. J Adv Prosthodont. 2020;12:218-24.
[21] Al-Halabi MN, Bshara N, Comisi JC, Nassar JA. Evaluation of fracture resistance force in three types of primary molar crowns: Milled by CAD\CAM, 3D dental printed, and composite celluloid crowns. European Dental Research and Biomaterials Journal. 2020;1:33-39.
[22] Othman A, Ströbele DA, Lüllmann A, Stehle O, Alevizakos V, See CV. Comparative mechanical testing for digitally produced provisional fixed partial dentures vs the conventional method: An in-vitro study. Int J Prosthodont. 2023;36(6):748-53.
[23] Tasın S, Ismatullaev A. Comparative evaluation of the effect of thermocycling on the mechanical properties of conventionally polymerized, CAD-CAM milled and 3D-printed interim materials. J Prosthet Dent. 2022;127:173.e1-173.e8.
[24] Baldi A, Comba A, Tempesta RM, Carossa M, Pereira GKR, Valandro LF, et al. External marginal gap variation and residual fracture resistance of composite and lithium-silicate CAD/CAM overlays after cyclic fatigue over endodontically-treated molars. Polymers. 2021;13:3002.
[25] Astudillo-Rubio D, Delgado-Gaete A, Bellot-Arcís C, Montiel-Company JM, Pascual-Moscardó A, Almerich-Silla JM. Mechanical properties of provisional dental materials: A systematic review and meta-analysis. PLoS ONE. 2018;13:e0193162.
[26] Alzahrani SJ, Hajjaj MS, Azhari AA, Ahmed WM, Yeslam HE, Carvalho RM. Mechanical properties of three-dimensional printed provisional resin materials for crown and fixed dental prosthesis: A systematic review. Bioengineering (Basel). 2023;10(6):663.
[27] Jain S, Sayed ME, Shetty M, Alqahtani SM, Al Wadei MHD, Gupta SG, et al. Physical and mechanical properties of 3D-printed provisional crowns and fixed dental prosthesis resins compared to CAD/CAM milled and conventional provisional resins: A systematic review and meta-analysis. Polymers (Basel). 2022;14(13):2691.
[28] Thompson GA, Luo Q. Contribution of postpolymerization conditioning and storage environments to the mechanical properties of three interim restorative materials. J Prosthet Dent. 2014;112:638-48.
[29] Cheng CJ, Lin CL, Shan YF. Multifactorial analysis of variables influencing the fracture strength of repair joints for provisional restorative materials using the statistically based Taguchi method. J Dent Sci. 2010;5:90-99.
[30] Suralik KM, Sun J, Chen CY, Lee SJ. Effect of fabrication method on fracture strength of provisional implant-supported fixed dental prostheses. Prosthesis. 2020;2:325-32.
[31] Kang SY, Park JH, Kim JH, Kim WC. Accuracy of provisional crowns made using stereolithography apparatus and subtractive technique. J Adv Prosthodont. 2018;10:354-60.
[32] Federick DR. The provisional fixed partial denture. J Prosthet Dent. 1975;34:520-26.
[33] Alharbi N, Osman RB, Wismeijer D. Effects of build direction on the mechanical properties of 3D-printed complete coverage interim dental restorations. J Prosthet Dent. 2016;115:760-67.
[34] Tahayeri A, Morgan M, Fugolin AP, Bompolaki D, Athirasala A, Pfeifer CS, et al. 3D printed versus conventionally cured provisional crown and bridge dental materials. Dent Mater. 2018;34:192-200.
[35] Madhav VNV, Digholkar, Palaskar J. Evaluation of the flexural strength and microhardness of provisional crown and bridge materials fabricated by different methods. J Indian Prosthodont Soc. 2016;16:328-34.
[36] Revilla-León M, Umorin M, Özcan M, Piedra-Cascón W. Colour dimensions of additive manufactured interim restora-tive dental material. J Prosthet Dent. 2020;123:754-60.
[37] Lodding DW. Long-term esthetic provisional restorations in dentistry. Curr Opin Cosmetic Dent. 1997;4:16-21.
[38] Trushkowsky RD. Fabrication of a fixed provisional restoration utilizing a light-curing acrylic resin. Quintessence Int. 1992;23:415-19.
[39] Proussaefs P. Immediate provisionalization with a CAD/CAM interim abutment and crown: A guided soft tissue healing technique. J Prosthet Dent. 2015;113:91-95.
[40] Liebermann A, Wimmer T, Schmidlin PR, Scherer H, Löffler P, Roos M, et al. Physic mechanical characterization of polyetherether ketone and current esthetic dental CAD/CAM polymers after aging in different storage media. J Prosthet Dent. 2016;115(3):321-28.e2.
[41] Alp G, Murat S, Yilmaz B. Comparison of flexural strength of different CAD/CAM PMMA-based polymers. J Prosthodont. 2019;28(2):e491-e495.
[42] Alt V, Hannig M, Wöstmann B, Balkenhol M. Fracture strength of temporary fixed partial dentures: CAD/CAM versus directly fabricated restorations. Dent Mater. 2011;27(4):339-47.
[43] Córdova N, Fajardo JI, Aliaga P. Comparative analysis of fracture resistance between CAD/CAM materials for interim fixed prosthesis. Materials. 2021;14:7791.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Jul 03, 2024
- Manual Googling: Nov 03, 2024
- iThenticate Software: Nov 05, 2024 (14%)

ETYMOLOGY: Author Origin

EMENDATIONS: 4

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? NA
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Jul 02, 2024**
Date of Peer Review: **Aug 27, 2024**
Date of Acceptance: **Nov 07, 2024**
Date of Publishing: **Feb 01, 2025**