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Review

# Marginal Adaptation and Internal Fit 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

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**Abstract:** The aim of this systematic review was to evaluate the marginal fit and internal adaptation of provisional crowns and fixed dental prostheses (FDPs) fabricated using 3D-printing resins and compared them with those fabricated by CAD/CAM (computer-aided designing/computer-aided manufacturing) milling and conventional resins. The null hypotheses tested were that there would be no differences in the marginal fit and internal adaptation of 3D-printed provisional crowns and FDP resins when compared to CAD/CAM-milled and conventional provisional resins. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to construct this systematic review. The focused PICO/PECO (Population, Intervention/Exposure, Comparison, Outcome) question was "Do provisional crowns and FDPs (P) fabricated by 3D-printing (I) have similar marginal adaptation and internal fit (O) when compared to those fabricated by CAD/CAM milling and conventional techniques (C)?". The protocol used for this systematic review was pre-registered in the International Prospective Register of Systematic Reviews (PROSPERO). Electronic databases (e.g., MEDLINE/PubMed and Web of Science (Core Collection)) were systematically searched for indexed English literature published up to June 2022. In the initial electronic search of the selected databases, 519 articles were identified. Duplicates were removed, and screening was performed to select the articles that met the preset inclusion criteria. Sixteen studies were selected for qualitative analysis, but only ten of them provided comparative data and were selected for quantitative analysis. The modified CONSORT scale was used for qualitative analysis, and most of the included studies were rated to be of moderate quality. Based on the findings, it could be concluded that provisional crowns and FDPs fabricated from 3D-printing resins have a superior marginal fit and internal adaptation when compared to CAD/CAM-milled and conventional provisional resins; thus, they can be used as a dependable alternative to other resins.

**Keywords:** PMMA; bis-acrylic resin; 3D printing; CAD/CAM; milling; provisional crowns; provisional fixed dental prosthesis; interim restoration; marginal fit; marginal adaptation; internal fit; internal adaptation; temporary crown; temporary fixed dental prosthesis

## 1. Introduction

Provisional crowns and fixed dental prostheses (FDPs) are an integral part of fixed prosthodontic treatment and play an important role in aesthetics, pulp protection, gingival tissue management, maintaining the position of the prepared teeth, and diagnosis and treatment planning [1–5].

While managing complex full-mouth rehabilitation cases and implant prosthodontics, provisional restorations might need to be in function for prolonged time periods. In order to serve adequately for longer durations, provisional resins should possess adequate physical and mechanical properties [6,7].

Conventional techniques for the fabrication of provisional crowns and FDPs involve using poly(methyl methacrylate) (PMMA), poly(ethyl methacrylate) (PEMA), bis-acrylic, and dimethacrylate resins [6], which can be used either chairside (direct technique) or in production labs (indirect technique). PMMA resins have some inherent shortcomings, including high polymerization shrinkage, poor stain resistance, and heat production during polymerization, which has been overcome to a great extent by using bis-acrylic resins [5,8,9].

Continuous advancements in the field of data collection and fabrication have made digital dentistry more popular [10] by making procedures simpler and more user-friendly. With the advent of computer-aided design and computer-aided manufacturing (CAD/CAM) technology, provisional restorations can be fabricated via CAD/CAM milling (a subtractive manufacturing technique). This involves the use of pre-polymerized resin blocks that are milled using computer-assisted machining tools [5,11]. When compared to conventional techniques, restorations manufactured by CAD/CAM milling have been reported to be more reliable and to require less manufacturing time [5,7,11–13]. Three-dimensional (3D) printing technology is recent compared to techniques and involves 3D printing of provisional resins using the layering technique [14–20]. The procedure is cost-effective and causes less wastage of materials [5,7,16,21–23]. Various generations of 3D-printing machines are available, with each having its own merits and demerits [10,14–20].

In general, it is reported that 3D-printed provisional crowns and FDP materials have superior mechanical properties, whereas CAD/CAM-milled provisional materials have better physical properties when compared to conventionally fabricated provisionals [24]. However, using CAD/CAM technology for provisional restorations has some disadvantages, which include expensive manufacturing devices [14], higher fabrication costs, and limitations in complex milling shapes, particularly on the intaglio surface [25].

Internal adaptation and marginal fit are crucial parameters to consider when selecting the material for the fabrication of provisional crowns and FDPs [5,25–28]. Good marginal fit prevents microleakage, cement dissolution, plaque accumulation, and secondary caries [25–32], whereas good internal adaptation improves the retention form, resistance form, and durability of the provisional restoration [25,29,33]. Multiple studies have been conducted to compare these two parameters, but they have reported varied results [5,7,10,14,25,34–44].

To the best of our knowledge, there is no published systematic review comparing the marginal fit and internal adaptation of 3D-printed provisional resins with those of resins used in CAD/CAM milling and conventional techniques. The question arises as to whether provisional crowns and FDPs fabricated using recently introduced 3D-printing technology have a comparable fit (internal and marginal) when compared to those fabricated using other techniques. Thus, the aim of this systematic review was to evaluate the marginal fit and internal adaptation of provisional crowns and FDPs fabricated using 3D-printing resins and compare them with those fabricated using CAD/CAM milling and conventional resins. The null hypotheses tested were that there would be no differences in marginal fit and internal adaptation of 3D-printed provisional crowns and FDP resins when compared to CAD/CAM-milled and conventional provisional resins.

## 2. Materials and Methods

### 2.1. Permission and Registration

The framework of this systematic review was constructed based on the guidelines set out in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [45]. The protocol used for this systematic review was pre-registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42022348367).

### 2.2. Eligibility Criteria

The inclusion and exclusion criteria used in this review are listed in Table 1.

**Table 1.** Inclusion and exclusion criteria.

| Inclusion Criteria | Exclusion Criteria |
|---|---|
| In vitro studies | Incomplete trials, unpublished abstracts, reports, commentaries, letters to the editor, case reports, technical reports, dissertations, cadaver studies, and opinion-based reviews [24] |
| Human clinical studies | Animal studies |
| Literature in the English language | Literature in any language other than English |
| Studies comparing the internal fit of the 3D-printed provisional fixed dental prostheses (FDPs) and crown materials with other materials and techniques used for the fabrication of provisional crowns and FDPs [24] | Studies comparing properties other than internal fit and marginal adaptation |
| Studies comparing the marginal adaptation of the 3D-printed provisional fixed dental prostheses (FDPs) and crown materials with other materials and techniques used for the fabrication of provisional crowns and FDPs [24] | Studies comparing only trueness, precision, 3D deviation, or accuracy of 3D-printed provisional materials with other types of provisional materials |
| - | Studies evaluating materials under trial. |
| - | Studies evaluating only 3D-printed provisional materials (examining the effects of various 3D-printing parameters, such as printing orientation, resin color setting, layer thickness, degree of conversion, etc., on marginal adaptation and internal fit) without comparing them with other types of provisional materials [24] |

### 2.3. Exposure and Outcome

The focused PICO/PECO (Population, Intervention/Exposure, Comparison, Outcome) question was "Do provisional crowns and FDPs (P) fabricated by 3D-printing (I) have similar marginal adaptation and internal fit (O) when compared to those fabricated by CAD/CAM milling and conventional techniques I?":

1. P—Provisional crowns and FDPs;
2. I—3D-printing method;
3. C—CAD/CAM milling or conventional methods;
4. O—Marginal adaptation and internal fit.

### 2.4. Search Strategy

The abovementioned PICO question was used in the search strategy. The electronic databases searched for indexed English literature were MEDLINE/PubMed, Scopus, Cochrane Library, and Web of Science (Core Collection). The systematic search was carried out in July 2022 by two independent authors (S.J. and A.A.) using the keywords (MeSH and non-MeSH) and Boolean operators listed in Table S1. A manual citation search was conducted for additional relevant articles that were not discovered during the electronic database search. Minor modifications in the search strategy were implemented to meet the requirements of each electronic search database.

### *2.5. Study Selection and Data Extraction*

After the initial electronic and manual search, duplicate articles were removed, and no difference was found in the list of articles. Two authors (M.E.S. and S.J.) used preset inclusion and exclusion criteria to screen the titles and abstracts of these selected articles. Subsequently, two authors (M.H.D.A.W. and N.M.A.) reviewed the full texts of titles that appeared to meet the inclusion criteria or in which the abstracts did not provide sufficient information to make a decision. Four authors (S.J, M.H.D.A.W., M.E.S. and N.M.A.) discussed the disputed articles to resolve any disagreements. Later, four authors (S.J., H.A., A.A.A. and A.H.A.) extracted the relevant data from the selected articles and tabulated them in two predesigned tables. Table 2 is a common table containing information related to authors' names, years of publication, types of study, characteristics studied, sample size, brands of materials evaluated, their main composition, fabrication techniques, abutment types, types of framework, types of scanning program, and scanners used. Table 3 provides detailed information related to the marginal adaptation and internal fit of provisional crowns and FDPs, including cement film thickness, type of 3D printer used, layer thickness and printing orientation, examination method used, mean marginal discrepancy and internal discrepancy, and authors' suggestions and conclusions.

**Table 2.** Summary of the studies included in the systematic review.

| Author and Year | Study Type | Studied Characteristics | Sample Size ($n$) | Trade Name and Manufacturer of the Evaluated Materials | Main Chemical Composition | Specimen Fabrication Technique | Abutment Type (Tooth/Implant) and Region | Type of Framework (Single Crown/ 3-Unit FPD) | Scanning Software Program/Scanner Used |
|---|---|---|---|---|---|---|---|---|---|
| Park et al., 2016 [14] | In vitro | MF and IF | $n$ = 120<br>(40 per group) | (A) Jet (Lang Dental Mfg Co Inc., Wheeling, IL, USA)<br>(B) Pekkton Ivory (Cendres & Metaux, Biel, Switzerland)<br>(C) E-Dent (Envision TEC, Gladbeck, Germany) | (A) PMMA<br>(B) PEEK<br>(C) PMMA | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C) 3D printing | Implant transfer abutment: maxillary and mandibular 2nd premolar and maxillary 1st molar region | Crown | Noncontact blue-light scanner (Identica Blue; Medit, Seoul, South Korea) |
| Lee et al., 2017 [43] | In vitro | IF | $n$ = 30<br>(10 per group) | (A) Vipi block (VIPI, Pirassununga, Brazil)<br>(B) VeroGlaze MED620 (Stratasys, Eden Prairie, MI, USA)<br>(C) ZMD-1000B (Dentis, Daegu, Korea) | (A) PMMA<br>(B) Acrylic formulation (photopolymer)<br>(C) Urethane methacrylate oligomer | (A) CAD/CAM milling<br>(B) 3D printing<br>(C) 3D Printing | Dental stone abutment tooth, maxillary 1st molar | Crown | Identica Hybrid, Medit, Seoul, Korea |
| Mai et al., 2017 [44] | In vitro | MF and IF | $n$ = 36<br>(12 per group) | (A) Alike (GC Europe, Leuven, Belgium)<br>(B) Ceramill TEMP (Amann Girrbach, Charlotte, NC, USA)<br>(C) VeroGlaze MED 620 (Stratasys, Rehovot, Israel) | (A) PMMA<br>(B) PMMA<br>(C) Acrylic formulation (Photopolymer) | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C) 3D printing | Dental stone study cast Crown: mandibular 1st molar | Crown | Desktop scanner (Ceramill Map 400; Amann Girrbach, Charlotte, NC, USA) |
| Alharbi et al., 2018 [10] | In vitro | MF and IF | $n$ = 80<br>(40 per group, 10 each for 4 different types of finish lines: KE, C, RS, RSB) | (A) Polycon ae (Straumann, Basel, Switzerland)<br>(B) Temporis: (DWS, Frankfurt am Main, Germany) | (A) PMMA<br>(B) Hybrid composite resin | (A) CAD/CAM milling<br>(B) 3D printing | Resin tooth, maxillary central incisor | Crown | Desktop optical scanner (Medit Identica Blue$^{TM}$; Renishaw, Wharton, UK) |
| Al Deeb et al., 2019 [36] | In Vitro | Marginal integrity and internal adaptation | $n$ = 30<br>(10 per group) | (A) TrimPlus, Bosworth, Keystone Dental, Gibbstown, NJ, USA<br>(B) Ceramill TEMP (Amann Girrbach, Charlotte, NC, USA)<br>(C) White Resin, Temporary CB (Formlabs, Somerville, MA, USA) | (A) PMMA<br>(B) PMMA<br>(C) PMMA | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C) SLA, 3D printing | Implant analogues mounted on blocks of orthodontic resin | 3-Unit fixed partial denture | Ceramill Map 400, Amann Girrbach, Charlotte, NC, USA |
| Peng et al., 2020 [5] | In vitro | IF and MD | $n$ = 36<br>(12 per group) | (A) Protemp Plus (3M ESPE, Seefeld, Germany)<br>(B) ZCAD Temp Fix (Harvest Dental, Brea, CA, USA)<br>(C) NextDent C&B MFH (NextDent by 3D system, Soesterberg, the Netherlands) | (A) Bis-acrylic composite resin<br>(B) PMMA<br>(C) Methacrylic oligomers | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C) 3D printing | Resin tooth, mandibular 1st molar | Crown | 3D laboratory scanner (D2000; 3Shape, Copenhagen, Denmark). |
| Earar et al., 2020 [42] | In vitro | IF | $n$ = 30<br>(10 per group) | N/M | (A) PMMA<br>(B) PMMA | (A) CAD/CAM milling<br>(B) 3D printing | Dental stone abutment tooth, mandibular 2nd premolar | Crown | Laboratory scanner AutoScan-DS200+ (Shining 3D) |

**Table 2.** *Cont.*

| Author and Year | Study Type | Studied Characteristics | Sample Size (*n*) | Trade Name and Manufacturer of the Evaluated Materials | Main Chemical Composition | Specimen Fabrication Technique | Abutment Type (Tooth/Implant) and Region | Type of Framework (Single Crown/ 3-Unit FPD) | Scanning Software Program/Scanner Used |
|---|---|---|---|---|---|---|---|---|---|
| Peng et al., 2020 [25] | In vitro | IF and MD | $n = 48$ (16 per group) | (A) Jet, (Lang Dental, Wheeling, IL, USA)<br>(B) ZCAD Temp Fix 98, Harvest Dental, Brea, CA, USA)<br>(C) (NextDent C&B MFH; NextDent by 3D system, Soesterberg, the Netherlands) | (A) Autopolymerized PMMA<br>(B) PMMA<br>(C) Methacrylic oligomers | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C) 3D printing | Stereolithic resin dies, mandibular 1st molar | Crown | Laboratory scanner (D2000; 3Shape) |
| Sampaio et al., 2020 [7] | In vitro | IF (CT) | $n = 48$ (24 each for veneer and crown and 6 per group according to fabrication method) | (A) Acrílico Marche, Marche<br>(B) Protemp3, M Espe<br>(C) Vipiblock, Trilux<br>(D) Raydent C&B for temporary crown and bridge, 3D materials | (A) Autopolymerized PMMA<br>(B) Bis-acrylic resin<br>(C) PMMA<br>(D) Hybrid composite resin | (A and B) Conventional self-curing<br>(C) CAD/CAM milling<br>(D) 3D printing | 3D-printed resin preparations<br>Veneer: maxillary central incisor<br>Crown: maxillary second molar | Veneer and crown | Intra-oral scanner (CEREC Omnicam, Charlotte, NC, USA) |
| Chaturvedi et al., 2020 [34] | In vitro | MF and IF | $n = 90$ (30 per group, 10 each for 3 different types of finish lines: C, RS, RSB) | (A) Protemp 4 (3M ESPE, Seefeld, Germany)<br>(B) Ceramil TEMP (Amann Girrbach, Koblach, Austria)<br>(C) Dental SG (Formlabs, Somerville, MA, USA) | (A) Bis-acrylic composite resin<br>(B) PMMA and methacrylic acid ester-based crosslinked resin<br>(C) Methacrylate oligomers | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C) 3D printing | Dental stone abutment tooth<br>Crown: maxillary second premolar | Crown | Desktop scanner (Ceramill Map 400; Amann Girrbach, Koblach, Austria) |
| Wu et al., 2021 [35] | In vitro | IF and MA | $n = 48$ (16 per group) | (A) Luxa crown (DMG America, Ridgefield Park, NJ, USA)<br>(B) Lava Ultimate (3M ESPE, Seefeld, Germany)<br>(C) Dima Print Denture Teeth (Kulzer North America, South Bend, IN, USA) | (A) Dimethacrylate resin<br>(B) Resin nanoceramic material<br>(C) PMMA | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C) 3D printing | 3D-printed resin dies, mandibular 1st molar | Crown | Model scanner (D2000, 3Shape) |
| Mohajeri et al., 2021 [41] | In vitro | MF | $n = 42$ (14 per group) | (A) GC Tempron (GC America Inc., Alsip, IL, USA)<br>(B) PMMA blocks (Yamahachi Dental MFG. Co., Gamagori, Japan)<br>(C) Freeprint Temp UV (Detax, Ettlingen, Germany) | (A) PMMA<br>(B) PMMA<br>(C) Methacrylate-based resins | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C) 3D printing | Implant transfer abutment: maxillary canine region | Crown | 3Shape Trios scanner (3Shape Trios; 3Shape, 3Shape Trios; 3Shape, Denmark, Denmark) |
| Aldahian et al., 2021 [40] | In vitro | IA and MI | $n = 30$ (10 per group) | (A) Jet Tooth Shade™ Self-Curing Acrylic Resin (Lang Dental Manufacturing Co Inc., Wheeling, IL, USA)<br>(B) Cercon base PMMA blocks; DeguDent GmbH, Hanau, Germany<br>(C) Freeprint Temp; DETAX GmbH & Co. KG, Ettlingen, Germany | (A) PMMA<br>(B) PMMA<br>(C) Methyl methacrylate | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C) 3D printing | Dental stone dies<br>Crown: mandibular 1st molar | Crown | S 50 Zenotec CAD; Wieland Dental, Pforzheim, Germany |

**Table 2.** *Cont.*

| Author and Year | Study Type | Studied Characteristics | Sample Size ($n$) | Trade Name and Manufacturer of the Evaluated Materials | Main Chemical Composition | Specimen Fabrication Technique | Abutment Type (Tooth/Implant) and Region | Type of Framework (Single Crown/ 3-Unit FPD) | Scanning Software Program/Scanner Used |
|---|---|---|---|---|---|---|---|---|---|
| Karasan et al., 2022 [38] | In vitro | IF | $n$ = 60<br>(10 per group)<br>(40 for 3D printing, divided into 4 groups based on the type of resin and printing technology) | (A) Protemp 4 (3M ESPE AG, Seefeld, Germany)<br>(B) Telio-CAD (Ivoclar Vivadent, Schaan, Liechtenstein)<br>(C: FL-ST) & (D: RS-ST) P-Pro-C&B (Institut Straumann AG, Basel, Switzerland)<br>(E: FL-SH) & (F: RS-SH) SHERAprint-cb (SHERA Werkstoff-Technologie GmbH & Co., Lemförde, Germany) | (A) Bis-acrylic composite resin<br>(B) PMMA<br>(C and D) Flowable, light-curing acrylic-based composite (matrix: methacrylate)<br>(E and F) Flowable, light-curing acrylic-based composite (matrix: methacrylate oligomers) | (A) Conventional self-curing<br>(B) CAD/CAM milling<br>(C–F) 3D printing | 3D-printed resin master model: replacing mandibular 1st molar (tooth number 45, 46, 47) | 3-Unit fixed partial denture | Iscan D104i, Imetric 3D SA, Courgenay, Switzerland |
| Sidhom et al., 2022 [37] | In vitro | MF | $n$ = 8<br>(4 per group) | (A) Tempo-CAD PMMA discs, on dent, Bornova, Turkey<br>(B) Temporary CB (Formlabs, Somerville, MA, USA) | (A) PMMA<br>(B) Esterification products of 4,40-isopropylidenediphenol | (A) CAD/CAM milling<br>(B) 3D printing | Dental stone dies, replacing mandibular 1st molar (tooth number 45, 46, 47) | 3-Unit fixed partial denture | TRIOS 3 basic (3Shape, Copenhagen, Denmark) |
| Thakare et al., 2022 [39] | In vitro | IF and MF | $n$ = 45<br>(15 per group)<br>(30 for 3D printing, divided into 2 groups based on the type of printing technology) | (A) Ruthinium CAD/CAM PMMA blank, Badia Polesine, Italy<br>(B) & (C) NextDent C&B MFH (3D Systems, Stone Mountain, SC, USA) | (A) PMMA<br>(B and C) Methacrylic oligomers | (A) CAD/CAM milling<br>(B and C) 3D printing | Metal master model, mandibular 1st molar | Crown | Imes-icore i3Dscan dental model scanner |

MF: marginal fit, IF: internal fit, MA: marginal adaptation, MD: marginal discrepancy, MI: marginal integrity, IA: internal adaptation, N/M: not mentioned, CAD/CAM: computer-aided design/computer-aided manufacturing, SLA: stereolithography, KE: knife edge, C: chamfer, RS: rounded shoulder, RSB: rounded shoulder with bevel.

**Table 3.** Marginal adaptation and internal fit results.

| Author and Year | Cement Film Thickness | 3D Printer/Milling Machine Used | Layer Thickness and Orientation of Printing | Cementation or Non-Cementation Technique | Examination Method | Mean Marginal Discrepancy/Gap (µm) | Mean Internal Discrepancy/Gap (µm) | Authors' Suggestions/Conclusions |
|---|---|---|---|---|---|---|---|---|
| Park et al., 2016 [14] | 30 µm | Milling: 4-axial milling; (Cendres & Metaux SA, Biel, Switzerland)<br>3D printer: DLP; (Perfactory PixCera; Envision TEC, Gladbeck, Germany). | N/M | N/M | Silicone replica method; digital microscope (KH-7700; Hirox) at ×160 magnification | (A) Conventional: 120.92 ± 1.12<br>(B) Milled: 58.02 ± 19.75<br>(C) 3D-printed: 56.85 ± 22.24 | (A) Conventional:<br>(i) Intermarginal discrepancy: 149.71 (±60.70)<br>(ii) Axiogingival: 47.97 (±19.14)<br>(iii) Axio-occlusal: 46.88 (±17.23)<br>(iv) Occlusal: 182.44 (±55.61)<br>(B) Milled:<br>(i) Intermarginal discrepancy: 96.70 (±25.38)<br>(ii) Axiogingival: 67.02 (±17.97)<br>(iii) Axio-occlusal: 81.41 (±30.64)<br>(iv) Occlusal: 197.87 (±42.18)<br>(B) 3D-printed:<br>(i) Intermarginal discrepancy: 108.50 (±35.21)<br>(ii) Axiogingival: 67.54 (±20.29)<br>(iii) Axio-occlusal: 79.57 (±28.35)<br>(iv) Occlusal: 167.81 (±41.86)<br>Mean discrepancy:<br>(A) Conventional: 100.20 ± 58.06<br>(B) Milled: 109.59 ± 71.53<br>(C) 3D-printed: 96.05 ± 50.23 | Internal fit and marginal fit ranking:<br>3D printing > milling > conventional method<br>All three methods were suitable, as the marginal discrepancy was within the clinically acceptable range<br>The mean occlusal discrepancy was larger than the mean intermarginal, axiogingival, and axio-occlusal discrepancies |
| Lee et al., 2017 [43] | 60 µm | (A) 3D-milling system, Zirkonzahn<br>(B) 3D-printing system, Stratasys<br>(C) 3D printing system, Dentis | N/M | N/M | Silicon replica method; image microscope system (EZVM-452M, SomeTech) at ×300 magnification | NA | (A) Milled:<br>(i) Intermarginal discrepancy: 119.1 ± 54.8<br>(ii) Axiogingival: 53.9 ± 23.2<br>(iii) Axio-occlusal: 247.0 ± 42.1<br>(iv) Occlusal: 266.3 ± 36.0<br>3D-printed (Stratasys):<br>(i) Intermarginal discrepancy: 115.6 ± 68.4<br>(ii) Axiogingival: 137.4 ± 57.7<br>(iii) Axio-occlusal: 171.0 ± 74.5<br>(iv) Occlusal: 172.4 ± 43.3<br>(C) 3D-printed (Dentis):<br>(i) Intermarginal discrepancy: 64.3 ± 30.1<br>(ii) Axiogingival: 93.8 ± 36.6<br>(iii) Axio-occlusal: 98.7 ± 30.2<br>(iv) Occlusal: 107.5 ± 34.5<br>*Mean discrepancy:*<br>(A) Milled: 171.6 ± 97.4<br>(B) 3D-printed (Stratasys): 149.1 ± 65.9<br>(C) 3D-printed (Dentis): 91.1 ± 36.4 | Internal fit ranking:<br>3D printing > milling |

**Table 3.** *Cont.*

| Author and Year | Cement Film Thickness | 3D Printer/Milling Machine Used | Layer Thickness and Orientation of Printing | Cementation or Non-Cementation Technique | Examination Method | Mean Marginal Discrepancy/Gap (µm) | Mean Internal Discrepancy/Gap (µm) | Authors' Suggestions/Conclusions |
|---|---|---|---|---|---|---|---|---|
| Mai et al., 2017 [44] | 60 µm | Milling: 5-axis milling machine (Ceramill Motion 2; Amann Girrbach)<br>3D printer: PolyJet 3D printer (Object Eden 260VS; Stratasys, Rehovot, Israel). | Layer thickness: 5 µm<br>Orientation: N/M | Non-cementation technique | Silicone replica method; microscope (MM-40; Nikon Corp, Tokyo, Japan) at ×50 magnification | Absolute marginal discrepancy<br>(A) Conventional: 163 ± 86<br>(B) Milled: ≈101 $^{\#\#}$<br>(C) 3D-printed: 99 ± 19 | (A) Conventional:<br>Axial: 87 ± 62 µm<br>Occlusal region: ≈186 and 217 $^{\#\#}$<br>(B) Milled:<br>Axial: 125 ±30 micro m<br>Occlusal region: 301 ± 74 and 328 ± 108<br>(B) 3D-printed:<br>Axial: 139 ± 23 mm<br>Occlusal region: ≈151 and 180 $^{\#\#}$ | Marginal fit ranking: 3D printing > milling > conventional method<br>Internal fit ranking: conventional method > 3D printing > milling<br>3D printing could be an alternative approach to fabricating interim crowns |
| Alharbi et al., 2018 [10] | 30 µm (Additional vertical space of 80 µm and a horizontal space of 30 micro m) | Milling: 5-axis milling machine (Wissner Ltd.; Göttingen, Germany)<br>3D printer: stereo-lithography-based 3D printer (DW028D, DWS) | Layer thickness: 50 µm<br>Orientation of printing: N/M | N/M | Micro-CT scanning and analysis (Skyscan 1072 Bruker micro-CT, Kontich, Belgium). at × 400 magnification | (A) Milling:<br>Vertical gap:<br>(i) KE: 39 ± 21<br>(ii) C: 40 ± 5<br>(iii) RS: 34 ± 13<br>(iv) RSB: 19 ± 4<br>Horizontal gap:<br>(i) KE: 31 ± 8<br>(ii) C: 25 ± 3<br>(iii) RS: 41 ± 8<br>(iv) RSB: 33 ± 4<br>AMD<br>(i) KE: 56 ± 25<br>(ii) C: 54 ± 5<br>(iii) RS: 52 ± 16<br>(iv) RSB: 38 ± 3<br>(B) 3D printing:<br>Vertical gap:<br>(i) KE: 16 ± 10<br>(ii) C: 25 ± 6<br>(iii) RS: 21 ± 4<br>(iv) RSB: 26 ± 10<br>Horizontal gap:<br>(i) KE: 25 ± 9<br>(ii) C: 22 ± 4<br>(iii) RS: 20 ± 3<br>(iv) RSB: 25 ± 4<br>Absolute marginal discrepancy (AMD)<br>(i) KE: 43 ± 23<br>(ii) C: 48 ± 8<br>(iii) RS: 41 ± 5<br>(iv) RSB: 33 ± 6 | (A) Milling:<br>Incisal gap:<br>(i) KE: 97 ± 17<br>(ii) C: 271 ± 18<br>(iii) RS: 259 ± 19<br>(iv) RSB: 208 ± 11<br>Mid-axial gap:<br>(i) KE: 80 ± 6<br>(ii) C: 84 ± 7<br>(iii) RS: 111 ± 9<br>(iv) RSB: 99 ± 7<br>(B) 3D printing:<br>Incisal gap:<br>(i) KE: 93 ± 14<br>(ii) C: 213 ± 31<br>(iii) RS: 210 ± 6<br>(iv) RSB: 161 ± 15<br>Mid-axial gap:<br>(i) KE: 39 ± 5<br>(ii) C: 45 ± 3<br>(iii) RS: 51 ± 4<br>(iv) RSB: 29 ± 2<br>Mean discrepancy<br>(A) Milling:<br>(i) KE: 89 ± 8<br>(ii) C: 177 ± 10<br>(iii) RS: 185 ± 11<br>(iv) RSB: 154 ± 7<br>(B) 3D printing:<br>(i) KE: 66 ± 8<br>(ii) C: 149 ± 15<br>(iii) RS: 130 ± 4<br>(iv) RSB: 95 ± 7 | Internal fit and marginal fit ranking:<br>3D printing > milling<br>IF and MF are more affected by fabrication methods compared to the type of finish line |

**Table 3.** *Cont.*

| Author and Year | Cement Film Thickness | 3D Printer/Milling Machine Used | Layer Thickness and Orientation of Printing | Cementation or Non-Cementation Technique | Examination Method | Mean Marginal Discrepancy/Gap (µm) | Mean Internal Discrepancy/Gap (µm) | Authors' Suggestions/Conclusions |
|---|---|---|---|---|---|---|---|---|
| Al Deeb et al., 2020 [36] | 200 µm | Milling:<br>(Ceramill Motion II, Amann Girrbach, NC, USA<br>3D Printer: SLA; Form 2, FORMLABS, Somerville, MA, USA | N/M | Non-cementation technique | Micro-CT scanner (Skyscan 1172 High Resolution, Brukker, Belgium). | (A) Conventional: 283.31 ± 98.67<br>(B) Milled: 68.24 ± 18.11<br>(C) 3D-printed: 84.70 ± 27.59 | (A) Conventional: 106.73 ± 54.98<br>(B) Milled: 77.75 ± 8.53<br>(C) 3D-printed: 85.8 ± 23.64 | Marginal fit ranking milling > 3D Printing > conventional method<br>Internal fit ranking: milling > 3D printing > conventional method |
| Peng et al., 2020 [5] | 75 µm | Milling: DWX-51D Milling Machine, Roland DGA Co. (Irvine, CA, USA)<br>3D printer: digital light processing (DLP), MiiCraft 125; Young Optics | N/M | Both non-cementation and cementation techniques | Non-cementation technique: silicone replica method<br>Cementation technique: µCT (X5000 CT system, North Star Imaging) | (i) Silicone replica method:<br>(A) Conventional: 260 ± 110<br>(B) CAD/CAM milling: 180 ± 60<br>(C) 3D printing: 160 ± 40<br>(ii) Micro-CT scan technique:<br>(A) Conventional: 240 ± 80<br>(B) CAD/CAM milling: 80 ± 40<br>(C) 3D printing: 80 ± 30 | (1) Micro-CT scan technique (2D)<br>(A) Conventional: 210 ± 110<br>(B) CAD/CAM milling: 160 ± 60<br>(C) 3D printing: 170 ± 40<br>(2) Cement space volume in $mm^3$<br>(i) Silicone replica method:<br>(A) Conventional: 59.18 ± 12.61<br>(B) CAD/CAM milling: 39.67 ± 5.88<br>(C) 3D printing: 36.55 ± 4.22<br>(ii) Micro-CT scan technique(3D):<br>(A) Conventional: 28.76 ± 4.70<br>(B) CAD/CAM milling: 23.21 ± 1.58<br>(C) 3D printing: 26.64 ±3.07 | Internal fit and marginal fit ranking:<br>3D printing = milling > conventional method |
| Earar et al.. 2020 [42] | 20 µm | Milling: 5-axis dental milling machine, Rolland DWX-50<br>3D printer: DLP: MoonRay S 100 (SprintRay, Los Angeles, CA, USA) | N/M | Non-cementation technique | Electronic digital caliper Powerfix Profi+ (OWIM G mbH-AG, Neckarsulm, Gaermany) | NA | Inner diameter of PMMA crowns obtained (in mm): (A) Milling:<br>(i) Gingival:<br>B-L: 5.81 ± 0.118<br>M-D: 4.74 ± 0.101<br>(ii) Occlusal<br>B-L: 4.78 ± 0.150<br>M-D: 3.80 ± 0.093<br>(B) 3D Printing:<br>(i) Gingival:<br>B-L: 5.81 ± 0.110<br>M-D: 4.63 ± 0.157<br>(ii) Occlusal<br>B-L: 4.69 ± 0.158<br>M-D: 3.74 ± 0.100 | Internal fit ranking:<br>3D printing > milling |
| Peng et al., 2020 [25] | 60 µm | Milling: DWX-51D Milling Machine; Roland DGA Co.<br>3D printer: DLP: MiiCraft 125; Young Optics | N/M | Both non-cementation and cementation techniques | Non-cementation technique: silicone replica method<br>Cementation technique: µCT (X5000 CT system, North Star Imaging) | Micro-CT scan technique (2D)<br>(A) Conventional: 240 ± 90<br>(B) CAD/CAM milling: ≈180 ##<br>(C) 3D printing: 160 ± 50 | (1) Micro-CT scan technique(2D)<br>(A) Conventional: 240 ± 120<br>(B) CAD/CAM milling: 170 ± 30<br>(C) 3D printing: 170 ± 40<br>(2) Cement space volume in $mm^3$<br>(i) Silicone replica method:<br>(A) Conventional: 92.04 ± 30.21<br>(B) CAD/CAM milling: 39.46 ± 5.45<br>(C) 3D printing: ≈36 ##<br>(ii) Micro-CT scan technique(3D):<br>(A) Conventional: 33.67 ± 6.91<br>(B) CAD/CAM milling: 24.09 ± 4.28<br>(C) 3D printing: ≈26 ## | Internal fit ranking:<br>3D printing = milling > conventional method<br>Marginal fit ranking:<br>3D printing ≥ milling > conventional method |

**Table 3.** *Cont.*

| Author and Year | Cement Film Thickness | 3D Printer/Milling Machine Used | Layer Thickness and Orientation of Printing | Cementation or Non-Cementation Technique | Examination Method | Mean Marginal Discrepancy/Gap (μm) | Mean Internal Discrepancy/Gap (μm) | Authors' Suggestions/Conclusions |
|---|---|---|---|---|---|---|---|---|
| Sampaio et al., 2020 [7] | N/M | Milling: CEREC MCXL; Dentsply Sirona<br>3D printer: SLA: Photon; Anycubic | Layer thickness: 100 μm<br>Orientation of printing: N/M | Cementation technique | μCT apparatus (μCT 40; Scanco Medical AG, Wangen-Brüttisellen, Switzerland). | NA | Mean cement film thickness in μm<br>(i) Veneer<br>(A) Conventional PMMA: 140 ± 30<br>(B) Bis-acrylic: 90 ± 40<br>(C) Milled: 180 ± 30<br>(D) 3D-printed: 320 ± 30<br>(ii) Crown<br>(A) Conventional PMMA: 340 ± 60<br>(B) Bis-acrylic: 280 ± 80<br>(C) Milled: 240 ± 40<br>(D) 3D-printed: 620 ± 80 | Internal fit ranking for veneer:<br>conventional bis-acrylic > conventional PMMA > milling > 3D printing<br>Internal fit ranking for crown:<br>milling > conventional bis-acrylic > conventional PMMA > 3D printing |
| Chaturvedi et al., 2020 [34] | No cementation space | Milling: 5 axis milling machine; Ceramill Motion 2; Amann Girrbach, Austria<br>3D printer: Form 2 3D printer Formlabs Inc., Somerville, MA, USA | Layer thickness: 50 μm Orientation of printing: N/M | Non-cementation technique | SEM at ×27 magnification | (A) Conventional<br>(i) C: 104.4 ± 34.1 and 106.7 ± 34.1<br>(ii) RS: 96.2 ± 24.3 and 98.4 ± 24.3<br>(iii) RSB: 92.2 ± 21.1 and 94.4 ± 21.1<br>(B) Milled<br>(i) C: 54.3 ± 11.3 and 56.6 ± 11.3<br>(ii) RS: 51.4 ± 13.7 and 53.6 ± 13.7<br>(iii) RSB: 39.3 ± 5.9 and 42.5 ± 5.9<br>(C) 3D-printed<br>(i) C: 43.4 ± 9.2 and 45.6 ± 9.2<br>(ii) RS: 32.6 ± 7.5 and 34.8 ± 7.5<br>(iii) RSB: 30.6 ± 5.3 and 32.8 ± 5.3 | (A) Conventional<br>(i) C:<br>(a) Axial:<br>45.1 ± 24.5 and 46.5 ± 24.5<br>(b) Occlusal:<br>223.2 ± 24.1, 263.2 ± 9.3, and 225.4 ± 24.1<br>(ii) RS:<br>(a) Axial:<br>71.6 ± 23.5 and 73 ± 23.5<br>(b) Occlusal:<br>214.6 ± 10.7, 145.5 ± 7.2, and 216.8 ± 10.7<br>(iii) RSB:<br>(a) Axial:<br>63.1 ± 13.4 and 64.4 ± 13.4<br>(b) Occlusal:<br>176.8 ± 28, 125.5 ± 7.7, and 179 ± 28<br>(B) Milled<br>(i) C:<br>(a) Axial:<br>83.4 ± 12.8 and 84.8 ± 12.8<br>(b) Occlusal:<br>265.6 ± 26, 172.2 ± 10.9, and 267.1 ± 26<br>(ii) RS:<br>(a) Axial:<br>130.7 ± 14.1 and 112 ± 14.1<br>(b) Occlusal:<br>258.3 ± 13.2, 165.2 ± 7.9, and 260.6 ± 13.2<br>(iii) RSB:<br>(a) Axial:<br>99.4 ± 8.4 and 110.7 ± 8.4<br>(b) Occlusal:<br>201.8 ± 22.2, 138.4 ± 10.9, and 206.1 ± 22.2<br>(C) 3D-printed | Internal fit ranking:<br>3D printing > conventional method > milling<br>Marginal fit ranking<br>3D printing > milling > conventional method<br>Marginal gap: lowest for rounded shoulder with bevel finish line |

**Table 3.** *Cont.*

| Author and Year | Cement Film Thickness | 3D Printer/Milling Machine Used | Layer Thickness and Orientation of Printing | Cementation or Non-Cementation Technique | Examination Method | Mean Marginal Discrepancy/Gap (μm) | Mean Internal Discrepancy/Gap (μm) | Authors' Suggestions/Conclusions |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | (i) C:<br>(a) Axial:<br>24.2 ± 11.5 and 25.5 ± 11.5<br>(b) Occlusal:<br>214.3 ± 21.3, 151.1 ± 14.1, and 216.5 ± 21.3<br>(ii) RS:<br>(a) Axial:<br>83.5 ± 12.1 and 84.5 ± 12.1<br>(b) Occlusal:<br>212.8 ± 6.8, 132.3 ± 6.2, and 214.4 ± 6.8<br>(iii) RSB:<br>(a) Axial:<br>82.2 ± 6.6 and 82.6 ± 6.6<br>(b) Occlusal:<br>162.9 ± 16.1, 151.1 ± 16, and 165.2 ± 16.1 | |
| Wu et al., 2021 [35] | 60 μm | Milling: 5-axis dental milling machine (DWX-51D, Roland DGA, Frenchs Forest, NSW, Australia)<br>3D printer: (cara® Print 4.0, Kulzer North America, South Bend, IN, USA) | N/M | Cementation technique | Internal Adaptation: silicone-checked method (measured using a microscope (FMA050; AmScope, Irvine, CA, USA) at ×10 magnification)<br>Marginal adaptation evaluated by<br>(a) PVS replica method (measured using a stereoscope (Measurescope 20; Nikon, Tokyo, Japan) at ×75 magnification)<br>(b) Swept-source optical coherence tomography (SS-OCT) scanning technique ((Yoshida Dental OCT, Yoshida Dental Mfg, Tokyo, Japan) | (A) Conventional<br>(a) Vertical marginal discrepancy:<br>(i) PVS replica method: 21.5 ± 30.3<br>(ii) OCT: 20.3 ± 41.5<br>(b) Horizontal marginal discrepancy:<br>(i) PVS replica method: 63.3 ± 55.2<br>(ii) OCT: 72.7 ± 59.5<br>(c) AMD:<br>(i) PVS replica method: 71.3 ± 64.9<br>(ii) OCT: 82.7 ± 65.8<br>(B) Milling:<br>(a) Vertical marginal discrepancy<br>(i) PVS replica method: 7.0 ± 20.1<br>(ii) OCT scanning technique: 4.5 ± 14.8<br>(b) Horizontal marginal discrepancy:<br>(i) PVS replica method: 94.8 ± 59.8<br>(ii) OCT scanning technique: 97.0 ± 54.3<br>(c) AMD<br>(i) PVS replica method: 96.9 ± 60.2<br>(ii) OCT: 99.6 ± 54.6<br>(C) 3D-printed<br>(a) Vertical marginal discrepancy:<br>(i) PVS replica method: 13.3 ± 24.2<br>(ii) OCT: 6.8 ± 18.4<br>(b) Horizontal marginal discrepancy:<br>(i) PVS replica method: 118.7 ± 67.7<br>(ii) OCT: 146.4 ± 36.6<br>(c) AMD<br>(i) PVS replica method: 120.8 ± 70.9<br>(ii) OCT: 143.1 ± 39.9 | Absolute internal discrepancy<br>(A) Conventional: ≈49 ##<br>(B) Milling: ≈70 ##<br>(C) 3D printing: ≈68 ## | Internal fit ranking: conventional method > 3D printing > milling<br>Marginal fit ranking: conventional method > milling > 3D printing |

**Table 3.** *Cont.*

| Author and Year | Cement Film Thickness | 3D Printer/Milling Machine Used | Layer Thickness and Orientation of Printing | Cementation or Non-Cementation Technique | Examination Method | Mean Marginal Discrepancy/Gap (µm) | Mean Internal Discrepancy/Gap (µm) | Authors' Suggestions/Conclusions |
|---|---|---|---|---|---|---|---|---|
| Mohajeri et al., 2021 [41] | N/M | Milling: rainbow TM mill, Dentium, South Korea<br>3D printer: digital light processing printer (Prodent Labx, Product Bonyan Mecatronic, Tabriz, Iran) | N/M | Non-cementation | Stereomicroscope (SZX16, Olympus, Tokyo, Japan) at ×100 magnification | Mean of marginal gap<br>(A) Conventional: 51.23 ± 21.7<br>(B) CAD/CAM milling: 75.28 ± 22.14<br>(C) 3D printing: 91.4 ± 36.07 | NA | Marginal fit ranking: conventional method > milling > 3D printing |
| Aldahian et al., 2021 [40] | N/M | Milling: CAD-CAM milling machine (Versamill; Axsys Dental solutions, Wixom, MI, USA).<br>3D Printer: stereolithography-based 3D printer (MiiCraft 125; MiiCraft, Jena, Germany) | Layer thickness: 50 µm<br>Orientation of printing: 0 degrees | N/M | Bruker micro CT (Skyscan 1173 high-energy spiral scan micro-CT; Skyscan NV, Kontich, Belgium) | (A) Conventional: 395.89 ± 80.33<br>(B) Milled: 244.95 ± 19.65<br>(C) 3D-printed: 211.87 ± 17.8 | (A) Conventional: 269.94 ± 64<br>(B) Milled: 269.52 ± 54.17<br>(C) 3D-printed: 197.82 ± 11.72 | Marginal fit ranking 3D printing > milling > conventional method<br>Internal fit ranking: 3D printing > milling = conventional method |
| Karasan et al., 2021 [38] | 30 µm | Milling: 5-axis milling Machine; Zenotec Select Hybrid, Wieland Dental, Germany<br>3D printer:<br>(C: FL-ST) and (E: FL-SH): SLA FormLabs 2, Form-Labs, Somerville, MA, USA<br>(D: RS-ST) DLP: P20II, Rapid-Shape, Heimsheim, Germany<br>(F: RS-SH) DLP: P30, Rapid-Shape, Heimsheim, Germany | (C and D) Layer thickness: 100 µm<br>Orientation of printing: 45 degrees<br>(E) Layer thickness: 40 µm<br>Orientation of printing: 45 degrees<br>(F) Layer thickness: 50 µm<br>Orientation of printing: 45 degrees | N/M | Optical laboratory scanner (Iscan D104i; Imetric 3D SA). Triple-scan method | Marginal<br>(A) Conventional self-curing<br>(i) Premolar: 165.5 ± 38.89<br>(ii) Molar: 188.38 ± 73.76<br>(B) CAD/CAM milling:<br>(i) Premolar: 117.60 ± 62.65<br>(ii) Molar: 83.31 ± 68.72<br>(C–F) 3D printing<br>(C) FL-ST:<br>(i) Premolar: 172.50 ± 30.70<br>(ii) Molar: 114.76 ± 17.13<br>(D) RS-ST:<br>(i) Premolar: 160.27 ± 33.69<br>(ii) Molar: 110.52 ± 24.3<br>(E) FL-SH:<br>(i) Premolar: 103.07 ± 18.01<br>(ii) Molar: 69.10 ± 23.25<br>(F) RS-SH<br>(i) Premolar: 130.92 ± 27.58<br>(ii) Molar: 102.35 ± 31.84 | Axial:<br>(A) Conventional self-curing<br>(i) Premolar: 90.49 ± 26.15<br>(ii) Molar: 101.7 ± 46.89<br>(B) CAD/CAM milling:<br>(i) Premolar: 109.72 ± 39.77<br>(ii) Molar: 93.94 ± 50.45<br>(C–F) 3D printing<br>(C) FL-ST:<br>(i) Premolar: 108.08 ± 15.07<br>(ii) Molar: 98.28 ± 13.13<br>(D) RS-ST:<br>(i) Premolar: 122.60 ± 25.14<br>(ii) Molar: 85.54 ± 11.85<br>(E) FL-SH:<br>(i) Premolar: 101.18 ± 6.81<br>(ii) Molar: 67.92 ± 14<br>(F) RS-SH<br>(i) Premolar: 100.13 ± 16.40<br>(ii) Molar: 79 ± 20.5<br>Occlusal:<br>(A) Conventional self-curing<br>(i) Premolar: 142.38 ± 44.28<br>(ii) Molar: 150.78 ± 73.74<br>(B) CAD/CAM milling:<br>(i) Premolar: 153.74 ± 70.41<br>(ii) Molar: 113.11 ± 82.95<br>(C–F) 3D printing | Marginal fit ranking (mean of premolar and molar):<br>FL-SH 3D > milling > RS-SH 3D > RS-ST 3D > FL-ST 3D > conventional method<br>Internal fit ranking (mean of premolar and molar):<br>FL-SH 3D > FL-ST 3D > RS-SH 3D > milling > RS-ST 3D > conventional method |

**Table 3.** *Cont.*

| Author and Year | Cement Film Thickness | 3D Printer/Milling Machine Used | Layer Thickness and Orientation of Printing | Cementation or Non-Cementation Technique | Examination Method | Mean Marginal Discrepancy/Gap (μm) | Mean Internal Discrepancy/Gap (μm) | Authors' Suggestions/Conclusions |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | (C) FL-ST:<br>(i) Premolar: 116.29 ± 28.23<br>(ii) Molar: 67.6 ± 8.84<br>(D) RS-ST:<br>(i) Premolar: 168.23 ± 36.33<br>(ii) Molar: 131.27 ± 11.74<br>(E) FL-SH:<br>(i) Premolar: 169.48 ± 52.14<br>(ii) Molar: 103.03 ± 23.79<br>(F) RS-SH<br>(i) Premolar: 155.33 ± 23.17<br>(ii) Molar: 128.12 ± 37.17<br>Total:<br>(A) Conventional self-curing<br>(i) Premolar: 128.04 ± 31.04<br>(ii) Molar: 170.98 ± 105.47<br>(B) CAD/CAM milling:<br>(i) Premolar: 143.55 ±48.68<br>(ii) Molar: 98.85 ± 63.95<br>(C–F) 3D printing<br>(C) FL-ST:<br>(i) Premolar: 130.83 ± 22.81<br>(ii) Molar: 97.27 ± 11.5<br>(D) RS-ST:<br>(i) Premolar: 147.82 ± 29.96<br>(ii) Molar: 107.98 ± 15.53<br>(E) FL-SH:<br>(i) Premolar: 117.07 ± 13.71<br>(ii) Molar: 79.48 ± 18.2<br>(F) RS-SH<br>(i) Premolar: 125.25 ± 19.83<br>(ii) Molar: 101.91 ± 28.22 | |
| Sidhom et al., 2022 [37] | 30–60 μm | Milling: five-axis milling machine (CAM 5-S1 impression milling machine software, 3Shape, Copenhagen, Denmark<br>3D Printer: Formlabs SLA 3D printer (Formlabs Inc., Somerville, MA, USA | Layer thickness: N/M<br>Orientation of printing: 0 degrees | Non-cementation technique | Stereomicroscope (Euromex, Microscope BV, Arnhem, The Netherlands) ×10 magnification | Vertical marginal gap:<br>(A) Milled:<br>(i) Mesial retainer: 34.4 ± 12.4<br>(ii) Distal retainer: 36.9 ± 17.9<br>(A) 3D-printed:<br>(i) Mesial retainer: 31.1 ± 4.3<br>(ii) Distal retainer: 29.9 ± 4.3 | NA | Marginal fit ranking: 3D printing > milling |

**Table 3.** *Cont.*

| Author and Year | Cement Film Thickness | 3D Printer/Milling Machine Used | Layer Thickness and Orientation of Printing | Cementation or Non-Cementation Technique | Examination Method | Mean Marginal Discrepancy/Gap (µm) | Mean Internal Discrepancy/Gap (µm) | Authors' Suggestions/Conclusions |
|---|---|---|---|---|---|---|---|---|
| Thakare et al., 2022 [39] | 60 micro m | Milling: Arum 5X-200<br>3D Printer:<br>(B) SLA, Formlabs form 2<br>(C) DLP, NextDent 5100 | N/M | Non-cementation technique | Silicon replica technique and stereomicroscope | Marginal discrepancy<br>(A) Milled: 113.10<br>(B) 3D-printed SLA: 90.21<br>(C) 3D-printed DLP: 65.15 | Internal discrepancy<br>(A) Milled:<br>(i) Mid-axial wall: 127.73<br>(ii) Axio-occlusal edge: 185.59<br>(iii) Center of occlusal region: 291.98<br>(B) 3D-printed SLA:<br>(i) Mid-axial wall: 100.78<br>(ii) Axio-occlusal edge: 127.01<br>(iii) Center of occlusal region: 206.74<br>(C) 3D-printed DLP:<br>(i) Mid-axial wall: 77.53<br>(ii) Axio-occlusal edge: 83.73<br>(iii) Center of occlusal region: 160.76<br>Overall internal discrepancy<br>(A) Milled: 179.60<br>(B) 3D-printed SLA: 131.18<br>(C) 3D-Printed DLP: 96.79 | Marginal fit ranking:<br>3D-printed DLP > 3D-printed SLA > milled<br>Internal fit ranking:<br>3D-printed DLP > 3D-printed SLA > milled |

##: Data retrieved from plot digitizer app. N/M: not mentioned, NA: not applicable, KE: knife edge, C: chamfer, RS: rounded shoulder, RSB: rounded shoulder with bevel, AMD: absolute marginal discrepancy, DLP, digital light processing, PVS: polyvinyl siloxane, OCT: optical coherence tomography ≈: approximately, FL-SH: Formlabs-SHERA-cb, FL-ST: Formlabs-P Pro Crown and Bridge, RS-SH: Rapid Shape-SHERA-cb, RS-ST: rapid Shape-P Pro Crown and Bridge.

### *2.6. Quality Assessment of the Included Studies*

Quality assessment of the selected studies was performed using the modified CONSORT scale for in vitro studies [46,47] (Table 4). The 14 items included in this scale were as follows: Item 1: Abstract containing structured summary of study design, methodology, results, and conclusions; Item 2a: Introduction should have scientific background and detailed explanation of rationale; Item 2b: Introduction should have study objectives with a defined hypothesis; Item 3: Methodology should contain approach used in the experiment with sufficient details to enable replication; Item 4: Precisely stated primary and secondary outcomes to enable comparison; Item 5: Details of how sample size was determined; Item 6: Details of how random allocation sequence was generated; Item 7: Method used for random allocation concealment; Item 8: Who implemented randomization? Item 9: If randomization is performed, how was blinding followed? Item 10: Statistical assessment; Item 11: Results outcome and estimation; Item 12: Study limitations; Item 13: Details related to funding; Item 14: Details related to the availability of study protocol, if available (Table 4).

**Table 4.** Quality analysis results of the included studies.

| **Item** ➡<br>**Studies** ⬇ | **1** | **2a** | **2b** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Park et al., 2016 [14] | Y | Y | Y | Y | Y | Y | N | N | N | N | Y | Y | Y | N | N |
| Lee et al., 2017 [43] | Y | Y | Y | Y | Y | N | N | N | N | N | Y | Y | Y | Y | N |
| Mai et al., 2017 [44] | Y | Y | Y | Y | Y | N | N | N | N | N | Y | Y | Y | Y | N |
| Alharbi et al., 2018 [10] | Y | Y | Y | Y | Y | N | N | N | N | Y | Y | Y | Y | Y | N |
| Al Deeb et al., 2019 [36] | Y | Y | Y | Y | Y | Y | N | N | N | N | Y | Y | Y | Y | N |
| Peng et al., 2020 [5] | Y | Y | Y | Y | Y | Y | N | N | N | N | Y | Y | Y | Y | N |
| Earar et al., 2020 [42] | Y | Y | Y | Y | Y | N | N | N | N | N | Y | Y | N | N | N |
| Peng et al., 2020 [25] | Y | Y | Y | Y | Y | Y | N | N | N | N | Y | Y | Y | Y | N |
| Sampaio et al., 2020 [7] | Y | Y | Y | Y | Y | N | N | N | N | N | Y | Y | Y | Y | N |
| Chaturvedi et al., 2020 [34] | Y | Y | Y | Y | Y | N | N | N | N | N | Y | N | N | Y | N |
| Wu et al., 2021 [35] | Y | Y | Y | Y | Y | Y | N | N | N | N | Y | Y | Y | Y | N |
| Mohajeri et al., 2021 [41] | Y | Y | Y | Y | Y | Y | N | N | N | N | Y | Y | Y | N | N |
| Aldahian et al., 2021 [40] | Y | Y | Y | Y | Y | N | N | N | N | N | Y | Y | Y | Y | Y |
| Karasan et al., 2022 [38] | Y | Y | Y | Y | Y | N | N | N | N | N | Y | Y | Y | Y | N |
| Sidhom et al., 2022 [37] | Y | Y | Y | Y | Y | Y | N | N | N | N | Y | Y | Y | Y | Y |
| Thakare et al., 2022 [39] | Y | Y | N | Y | Y | N | N | N | N | N | Y | N | Y | N | N |

Note: Y: Yes, N: No.

### *2.7. Quantitative Assessment*

The data from the studies were compiled in a tabular format, and a meta-analysis was performed using RevMan (Review Manager) Version 5.4.1. (The Cochrane Collaboration, London, UK, 2020) [48]. The 3 types of 3D-printed crowns—methacrylate oligomers, methacrylate-based provisional resins, and hybrid composites—were compared to conventional bis-acrylic, conventional PMMA resin, and CAD/CAM-milled PMMA. The parameters considered were marginal discrepancy and internal discrepancy, which were converted to micrometers, i.e., continuous scale. Thus, an inverse variance was used to calculate the standardized mean difference using a fixed-effects model. Subgroups were constructed based on studies conducted on single crowns or 3-unit FDPs. The forest plots created showed the pooled results for each subgroup as well as the overall pooled standardized mean difference with a 95% confidence interval; *p*-values were calculated for the effects, and if they were less than 0.05, the null hypothesis was rejected. The heterogeneity was measured using the chi-squared test and I2 statistics and reported for subgroups as well as overall results.

## 3. Results

### *3.1. Identification and Screening*

The initial electronic search of the selected databases found 519 hits (PubMed: 169; Scopus: 182; Web of Science: 149; Cochrane: 19); 97 titles were found to be duplicates and were removed. Of the remaining 422 articles whose titles and abstracts were reviewed, 385 were rejected because they did not meet the inclusion criteria. The full text of the remaining 37 articles was reviewed based on the inclusion criteria. After a manual search of the references of these articles, one additional article was selected for full-text review. Of these 38 articles, 22 were rejected: eight articles evaluated the internal adaptation and marginal fit of only 3D-printed materials without comparing them with other types of materials; ten discussed only precision and/or trueness; two compared the effects of different curing methods on the internal adaptation/seating of 3D-printed crowns; one evaluated microleakage using different types of cement; and one evaluated the marginal accuracy of only resin-based ceramics with 3D-printed provisional materials. Thus, the final synthesis included 16 articles for qualitative analysis, of which only 10 provided comparative data and were selected for meta-analysis (Figure 1).

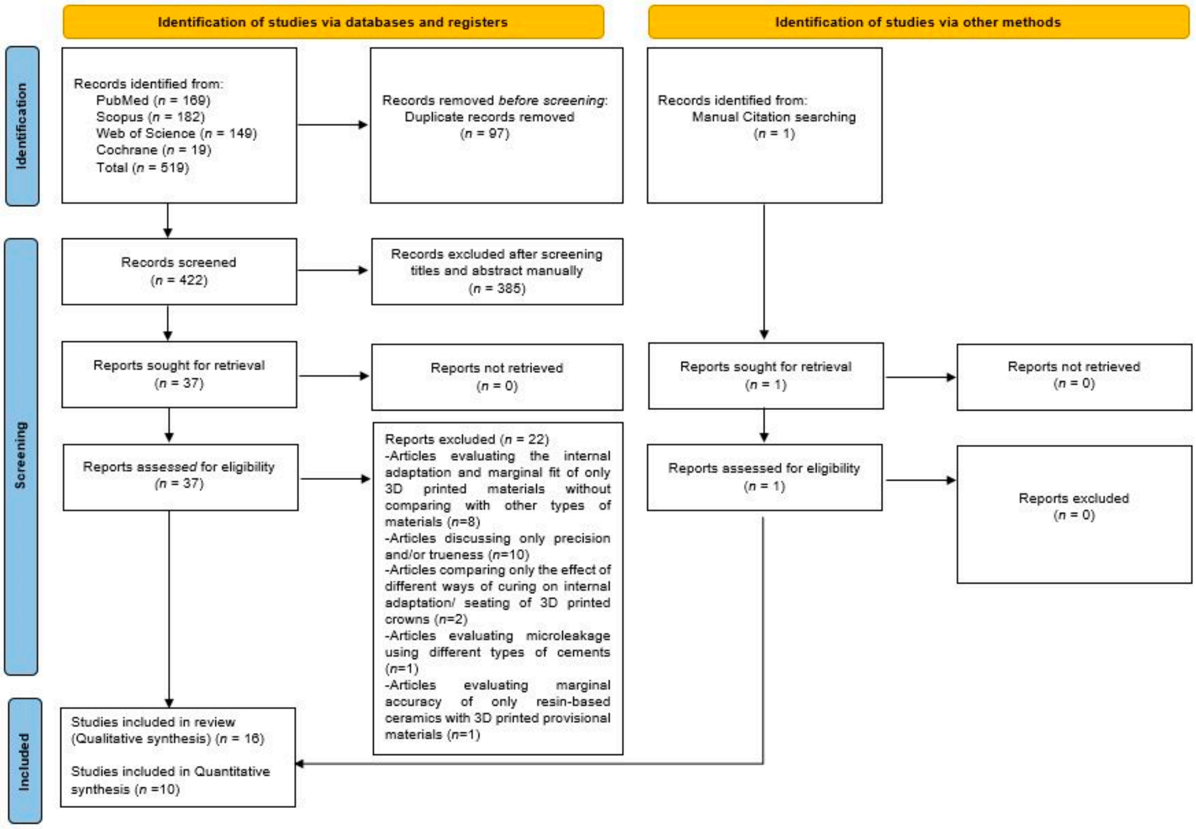


**Figure 1.** Article selection strategy based on PRISMA guidelines.

### *3.2. Quality Assessment of the Included Studies*

Sixteen in vitro studies met the inclusion criteria and were selected for this systematic review; 62% of the entries were positively reported. Items 1–4 and 10 (abstract, introduction, intervention, outcome, and statistical method, respectively) were reported by all 15 studies. Fourteen studies discussed the limitations (Item 12) and reported the precision of results as confidence intervals (Item 11). Twelve studies mentioned the source of funding (Item 13).

Seven studies reported the sample size calculation details (Item 5), two studies gave details related to the accessibility of the full trial protocol (Item 14), and only one study provided details about blinding to avoid operator-based bias (Item 9). None of the studies discussed any details related to randomization (Items 6–8) (Table 4).

### *3.3. Study Characteristics*

All 16 studies included in this review were in vitro studies, and the majority of them (15 out of 16) were published in the last 5 years. Eleven studies analyzed and compared both marginal fit and internal adaptation, three analyzed only internal adaptation, and two studies analyzed only the marginal fit of provisional crowns and FDPs. Relevant data obtained from these 16 studies are discussed under two subheadings according to the aims of this research.

Thirteen studies compared the marginal fit, while fourteen studies compared the internal adaptation of 3D-printed provisional resins with that of other materials (Tables 3 and 4). Of the 16 included studies, 6 used resin typodont teeth, 6 used dental stone abutment teeth, 3 used implant abutments, and 1 used a metal master model for the evaluation of the studied property. In order to evaluate and measure the discrepancies, seven studies used a micro-CT scanner, seven used the silicone replica technique and a digital microscope, and one each used a stereomicroscope, optical scanner, scanning electron microscope, and electronic digital caliper.

### *3.4. Results of Studies Analyzing the Marginal Fit*

Of the 13 studies comparing the marginal fit of provisional restorations, 9 studies used a single crown, 3 studies used a three-unit FDP (fixed dental prosthesis), and 1 study used both a single crown and a veneer.

#### 3.4.1. Comparing the Marginal Discrepancy Values of PMMA-Based 3D-Printed Provisional Resins

(i) Comparing the marginal discrepancy values of PMMA-based 3D-printed provisional resins with conventional PMMA-based resins:

    (A) Evaluation performed on single crowns: One study reported lower marginal discrepancies for PMMA-based 3D-printed provisional resins when compared to conventional PMMA-based resins [14].
    (B) Evaluation performed on three-unit FDPs: Al Deeb et al. [36] reported lower marginal discrepancies for PMMA-based 3D-printed provisional resins when compared to conventional PMMA-based resins.

(ii) Comparing the marginal discrepancy values of PMMA-based 3D-printed provisional resins with CAD/CAM-milled PEEK resins:

    (A) Evaluation performed on single crowns: Higher marginal discrepancies were reported when PMMA-based 3D-printed provisional resins were compared to CAD/CAM-milled PEEK resins [14].

(iii) Comparing the marginal discrepancy values of PMMA-based 3D-printed provisional resins with conventional dimethacrylate resins:

    (A) Evaluation performed on single crowns: Higher marginal discrepancies were reported when PMMA-based 3D-printed provisional resins were compared to conventional dimethacrylate resins [35].

(iv) Comparing the marginal discrepancy values of PMMA-based 3D-printed provisional resins with CAD/CAM-milled PMMA resins:

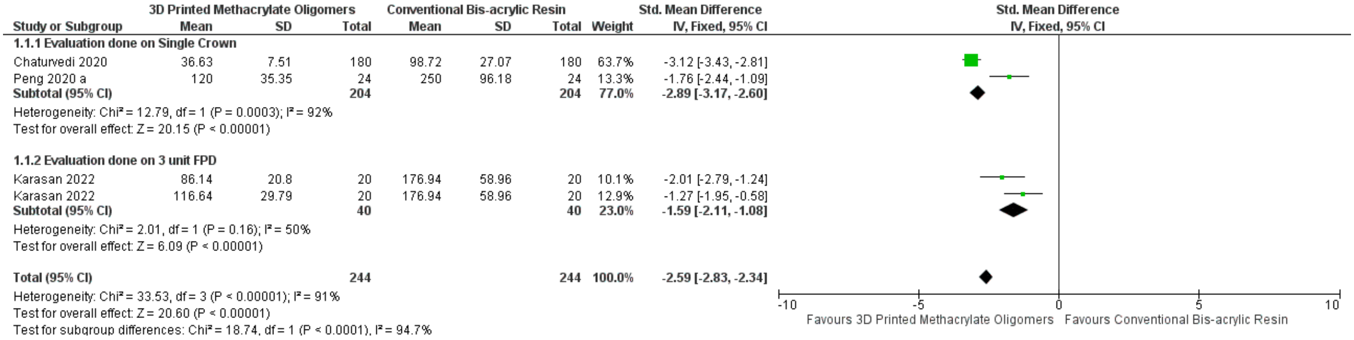
    (A) Evaluation performed on three-unit FDPs: Al Deeb et al. [36] reported higher marginal discrepancies for PMMA-based 3D-printed provisional resins when compared to CAD/CAM-milled PMMA resins.

### 3.4.2. Comparing the Marginal Discrepancy Values of 3D-Printed Methacrylate Oligomers

(i) Comparing the marginal discrepancy values of 3D-printed methacrylate oligomers with conventional bis-acrylic provisional resins:

 (A) Evaluation performed on single crowns: Lower marginal discrepancies were reported for 3D-printed methacrylate oligomers when compared to conventional bis-acrylic provisional resins [5,34] (Figure 2). The pooled SMD was −2.89 (−3.17 to −2.60) in favor of 3D-printed methacrylate oligomers and was statistically significant ($p < 0.05$).

 (B) Evaluation performed on three-unit FDPs: Karasan et al. [38] compared two different brands of 3D-printed methacrylate oligomers and reported lower marginal discrepancies when compared to conventional bis-acrylic provisional resins (Figure 2). The pooled SMD was −1.59 (−2.11 to −1.08) in favor of 3D-printed methacrylate oligomers and was statistically significant ($p < 0.05$).



| Study or Subgroup | 3D Printed Methacrylate Oligomers Mean | SD | Total | Conventional Bis-acrylic Resin Mean | SD | Total | Weight | Std. Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| **1.1.1 Evaluation done on Single Crown** | | | | | | | | |
| Chaturvedi 2020 | 36.63 | 7.51 | 180 | 98.72 | 27.07 | 180 | 63.7% | -3.12 [-3.43, -2.81] |
| Peng 2020 a | 120 | 35.35 | 24 | 250 | 96.18 | 24 | 13.3% | -1.76 [-2.44, -1.09] |
| **Subtotal (95% CI)** | | | **204** | | | **204** | **77.0%** | **-2.89 [-3.17, -2.60]** |
| Heterogeneity: Chi² = 12.79, df = 1 (P = 0.0003); I² = 92% | | | | | | | | |
| Test for overall effect: Z = 20.15 (P < 0.00001) | | | | | | | | |
| **1.1.2 Evaluation done on 3 unit FPD** | | | | | | | | |
| Karasan 2022 | 86.14 | 20.8 | 20 | 176.94 | 58.96 | 20 | 10.1% | -2.01 [-2.79, -1.24] |
| Karasan 2022 | 116.64 | 29.79 | 20 | 176.94 | 58.96 | 20 | 12.9% | -1.27 [-1.95, -0.58] |
| **Subtotal (95% CI)** | | | **40** | | | **40** | **23.0%** | **-1.59 [-2.11, -1.08]** |
| Heterogeneity: Chi² = 2.01, df = 1 (P = 0.16); I² = 50% | | | | | | | | |
| Test for overall effect: Z = 6.09 (P < 0.00001) | | | | | | | | |
| **Total (95% CI)** | | | **244** | | | **244** | **100.0%** | **-2.59 [-2.83, -2.34]** |
| Heterogeneity: Chi² = 33.53, df = 3 (P < 0.00001); I² = 91% | | | | | | | | |
| Test for overall effect: Z = 20.60 (P < 0.00001) | | | | | | | | |
| Test for subgroup differences: Chi² = 18.74, df = 1 (P < 0.0001), I² = 94.7% | | | | | | | | |

**Figure 2.** Forest plot comparing the marginal discrepancy values of 3D-printed methacrylate oligomers and conventional bis-acrylic resin for evaluations performed on single crowns (1.1.1) and on 3-unit FDPs (1.1.2). a: [5].

The overall SMD was −2.59 (−2.83 to −2.34) in favor of 3D-printed methacrylate oligomers over conventional bis-acrylic resin and was statistically significant ($p < 0.05$).

(ii) Comparing the marginal discrepancy values of 3D-printed methacrylate oligomers with CAD/CAM-milled PMMA provisional resins:

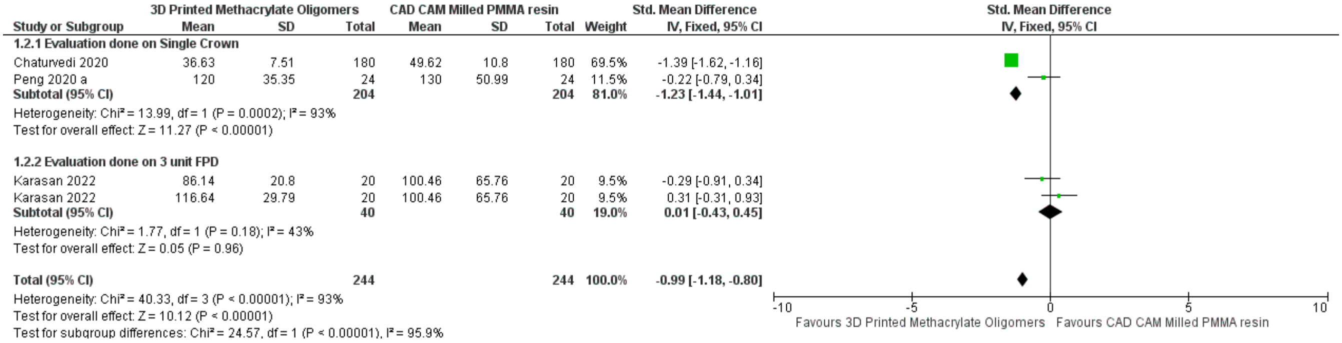
 (A) Evaluation performed on single crowns: Lower marginal discrepancies were reported for 3D-printed methacrylate oligomers when compared to CAD/CAM-milled PMMA provisional resins [5,25,34,39,44] (Figure 3). The pooled SMD was −1.23 (−1.44 to −1.01) in favor of 3D-printed methacrylate oligomers and was statistically significant ($p < 0.05$).

 (B) Evaluation performed on three-unit FDPs: Lower marginal discrepancies were reported for CAD/CAM-milled PMMA provisional resins when compared to two different brands of 3D-printed methacrylate oligomers [38] (Figure 3). The pooled SMD was 0.01 (−0.43 to 0.45) and was statistically insignificant ($p > 0.05$).

The overall SMD was −0.99 (−1.18 to −0.80) in favor of 3D-printed methacrylate oligomers over CAD/CAM-milled PMMA resin and was statistically significant ($p < 0.05$).

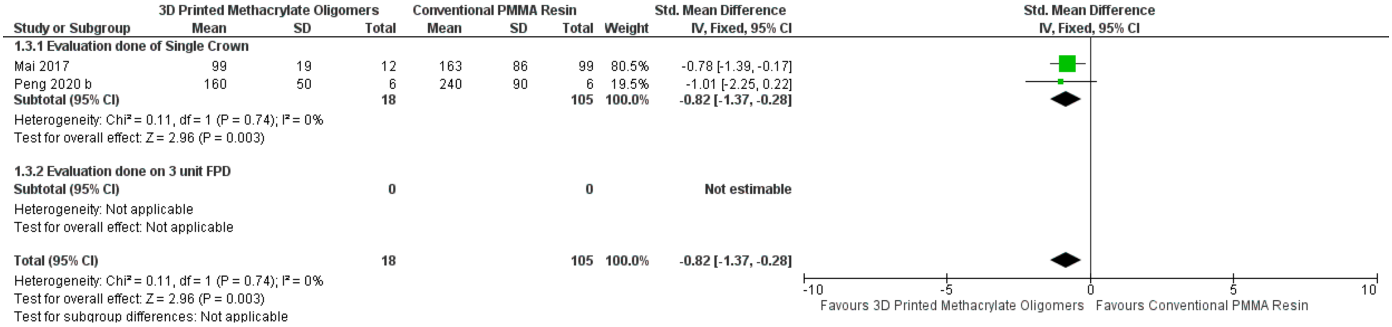
(iii) Comparing the marginal discrepancy values of 3D-printed methacrylate oligomers with conventional PMMA resins:

 (A) Evaluation performed on single crowns: Lower marginal discrepancies were reported for 3D-printed methacrylate oligomers when compared to conventional PMMA resin [25,44] (Figure 4). The overall SMD was −0.82 (−1.37 to −0.28) in favor of 3D-printed methacrylate oligomers over conventional PMMA resin and was statistically significant ($p < 0.05$).



| | 3D Printed Methacrylate Oligomers | | | CAD CAM Milled PMMA resin | | | | Std. Mean Difference |
|---|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | IV, Fixed, 95% CI |
| **1.2.1 Evaluation done on Single Crown** | | | | | | | | |
| Chaturvedi 2020 | 36.63 | 7.51 | 180 | 49.62 | 10.8 | 180 | 69.5% | -1.39 [-1.62, -1.16] |
| Peng 2020 a | 120 | 35.35 | 24 | 130 | 50.99 | 24 | 11.5% | -0.22 [-0.79, 0.34] |
| **Subtotal (95% CI)** | | | **204** | | | **204** | **81.0%** | **-1.23 [-1.44, -1.01]** |
| Heterogeneity: Chi² = 13.99, df = 1 (P = 0.0002); I² = 93% | | | | | | | | |
| Test for overall effect: Z = 11.27 (P < 0.00001) | | | | | | | | |
| **1.2.2 Evaluation done on 3 unit FPD** | | | | | | | | |
| Karasan 2022 | 86.14 | 20.8 | 20 | 100.46 | 65.76 | 20 | 9.5% | -0.29 [-0.91, 0.34] |
| Karasan 2022 | 116.64 | 29.79 | 20 | 100.46 | 65.76 | 20 | 9.5% | 0.31 [-0.31, 0.93] |
| **Subtotal (95% CI)** | | | **40** | | | **40** | **19.0%** | **0.01 [-0.43, 0.45]** |
| Heterogeneity: Chi² = 1.77, df = 1 (P = 0.18); I² = 43% | | | | | | | | |
| Test for overall effect: Z = 0.05 (P = 0.96) | | | | | | | | |
| **Total (95% CI)** | | | **244** | | | **244** | **100.0%** | **-0.99 [-1.18, -0.80]** |
| Heterogeneity: Chi² = 40.33, df = 3 (P < 0.00001); I² = 93% | | | | | | | | |
| Test for overall effect: Z = 10.12 (P < 0.00001) | | | | | | | | |
| Test for subgroup differences: Chi² = 24.57, df = 1 (P < 0.00001), I² = 95.9% | | | | | | | | |

**Figure 3.** Forest plot comparing the marginal discrepancy values of 3D-printed methacrylate oligomers and CAD/CAM-milled PMMA provisional resins for evaluations performed on single crowns (1.2.1) and on 3-unit FDPs (1.2.2). a: [5].



| | 3D Printed Methacrylate Oligomers | | | Conventional PMMA Resin | | | | Std. Mean Difference |
|---|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | IV, Fixed, 95% CI |
| **1.3.1 Evaluation done of Single Crown** | | | | | | | | |
| Mai 2017 | 99 | 19 | 12 | 163 | 86 | 99 | 80.5% | -0.78 [-1.39, -0.17] |
| Peng 2020 b | 160 | 50 | 6 | 240 | 90 | 6 | 19.5% | -1.01 [-2.25, 0.22] |
| **Subtotal (95% CI)** | | | **18** | | | **105** | **100.0%** | **-0.82 [-1.37, -0.28]** |
| Heterogeneity: Chi² = 0.11, df = 1 (P = 0.74); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 2.96 (P = 0.003) | | | | | | | | |
| **1.3.2 Evaluation done on 3 unit FPD** | | | | | | | | |
| **Subtotal (95% CI)** | | | **0** | | | **0** | | **Not estimable** |
| Heterogeneity: Not applicable | | | | | | | | |
| Test for overall effect: Not applicable | | | | | | | | |
| **Total (95% CI)** | | | **18** | | | **105** | **100.0%** | **-0.82 [-1.37, -0.28]** |
| Heterogeneity: Chi² = 0.11, df = 1 (P = 0.74); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 2.96 (P = 0.003) | | | | | | | | |
| Test for subgroup differences: Not applicable | | | | | | | | |

**Figure 4.** Forest plot comparing the marginal discrepancy values of 3D-printed methacrylate oligomers and conventional PMMA provisional resins for evaluations performed on single crowns (1.3.1). b: [25].

### 3.4.3. Comparing the Marginal Discrepancy Values of Methacrylate-Based 3D-Printed Provisional Resins

(i) Comparing the marginal discrepancy values of methacrylate-based 3D-printed provisional resins with conventional PMMA resins:

  (A) Evaluation performed on single crowns: Aldahian et al. [40] reported lower marginal discrepancies, whereas Mohajeri et al. [41] reported higher marginal discrepancies for methacrylate-based 3D-printed provisional resins when compared to conventional PMMA resins (Figure 5). The overall SMD was 0.14 (−1.18 to −0.80) in favor of 3D-printed methacrylate resin over CAD/CAM-milled PMMA resin and was statistically significant ($p < 0.05$).

(ii) Comparing the marginal discrepancy values of methacrylate-based 3D-printed provisional resins with CAD/CAM-milled PMMA resins:

  (A) Evaluation performed on single crowns: Aldahian et al. [40] reported lower marginal discrepancies, whereas Mohajeri et al. [41] reported higher marginal discrepancies for methacrylate-based 3D-printed provisional resins when compared to CAD/CAM-milled PMMA resins (Figure 6). The pooled SMD was −0.23 (−0.84 to 0.39) and was statistically insignificant ($p > 0.05$).

  (B) Evaluation performed on three-unit FDPs: Karasan et al. [38] compared two different brands of 3D-printed methacrylate resins and reported higher marginal discrepancies when compared to CAD/CAM-milled PMMA resins (Figure 6). The pooled SMD was 0.76 (0.30 to 1.22) in favor of CAD/CAM-milled PMMA resins and was statistically significant ($p < 0.05$).

The overall SMD was 0.41 (0.04 to 0.77) in favor of CAD/CAM-milled PMMA resins over 3D-printed methacrylate resins and was statistically significant ($p < 0.05$).

(iii) Comparing the marginal discrepancy values of methacrylate-based 3D-printed provisional resins with conventional bis-acrylic provisional resins:
    (A) Evaluation performed on three-unit FDPs: Karasan et al. [38] compared two different brands of 3D-printed methacrylate resins and reported lower marginal discrepancies when compared to conventional bis-acrylic provisional resins (Figure 7). The overall SMD was −0.80 (−1.25 to −0.34) in favor of 3D-printed methacrylate resins over conventional bis-acrylic resins and was statistically significant ($p < 0.05$).

#### 3.4.4. Comparing the Marginal Discrepancy Values of 3D-Printed Hybrid-Composite-Based and Isopropyl-Diphenol-Based Provisional Resins

(i) Comparing the marginal discrepancy values of 3D-printed hybrid-composite-based and isopropyl-diphenol-based provisional resins with CAD/CAM-milled PMMA resins:
    (A) Evaluation performed on single crowns: Alharabi et al. [10] reported lower marginal discrepancies for hybrid-composite-based 3D-printed provisional resins when compared to CAD/CAM-milled PMMA resins.
    (B) Evaluation performed on three-unit FDPs: Sidhom et al. [37] reported lower marginal discrepancies for isopropyl-diphenol-based 3D-printed provisional resins when compared to CAD/CAM-milled PMMA resins.

### *3.5. Results of Studies Analyzing the Internal Adaptation*

Nine out of thirteen studies comparing the internal adaptation used single crowns, three used three-unit FDPs, and one study used both a single crown and a veneer.

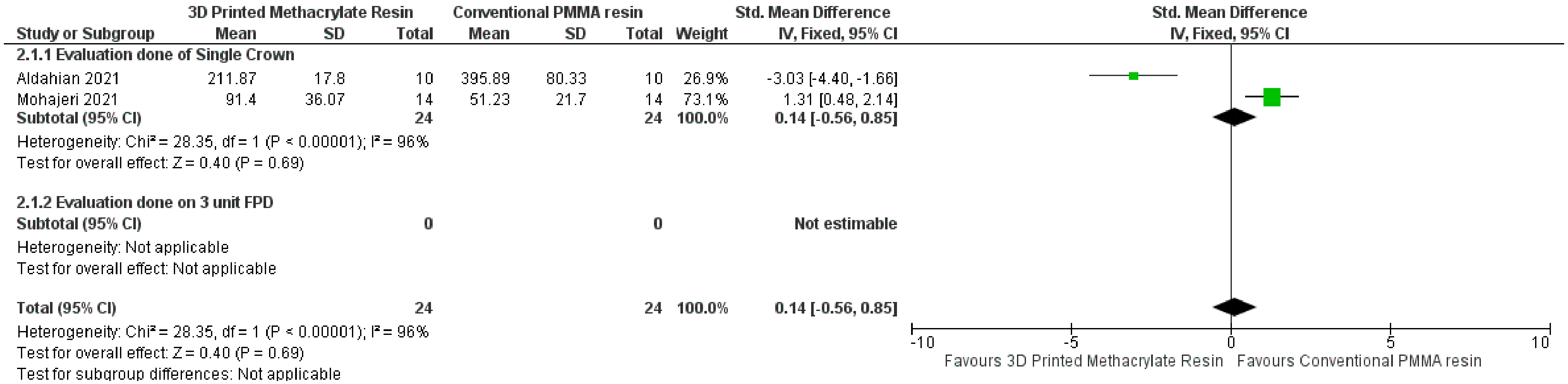
#### 3.5.1. Comparing the Internal Discrepancy Values of PMMA-Based 3D-Printed Provisional Resins

(i) Comparing the internal discrepancy values of PMMA-based 3D-printed provisional resins with conventional PMMA resin:
    (A) Evaluation performed on single crowns: Lower internal discrepancies were reported when PMMA-based 3D-printed provisional resins were compared to conventional PMMA resins [14].
    (B) Evaluation performed on three-unit FDPs: Al Deeb et al. [36] reported lower internal discrepancies for PMMA-based 3D-printed provisional resins when compared to conventional PMMA-based resins.

(ii) Comparing the internal discrepancy values of PMMA-based 3D-printed provisional resins with conventional dimethacrylate resin:
    (A) Evaluation performed on single crowns: Lower internal discrepancies were reported when PMMA-based 3D-printed provisional resins were compared to conventional dimethacrylate resin [35].

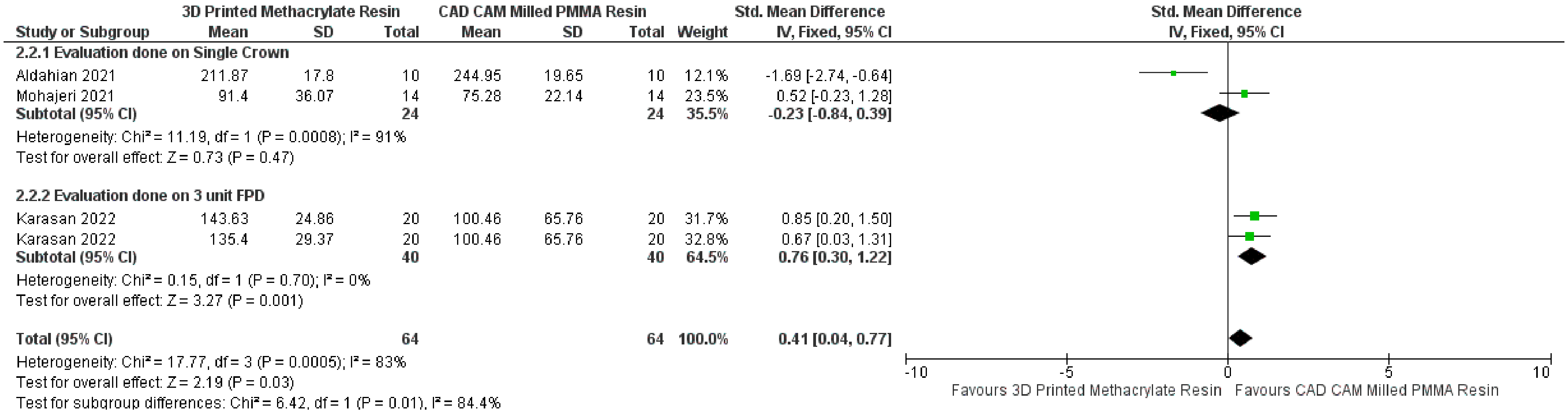
(iii) Comparing the internal discrepancy values of PMMA-based 3D-printed provisional resins with CAD/CAM-milled PEEK resin:
    (A) Evaluation performed on single crowns: Lower internal discrepancies were reported when PMMA-based 3D-printed provisional resins were compared to CAD/CAM-milled PEEK resin [14].

(iv) Comparing the internal discrepancy values of PMMA-based 3D-printed provisional resins with CAD/CAM-milled PMMA provisional resins:
    (A) Evaluation performed on single crowns: Lower internal discrepancies were reported when PMMA-based 3D-printed provisional resins were compared to CAD/CAM-milled PMMA provisional resins [36].
    (B) Evaluation performed on three-unit FDPs: Al Deeb et al. reported higher internal discrepancies for PMMA-based 3D-printed provisional resins when compared to CAD/CAM-milled PMMA resin [36].



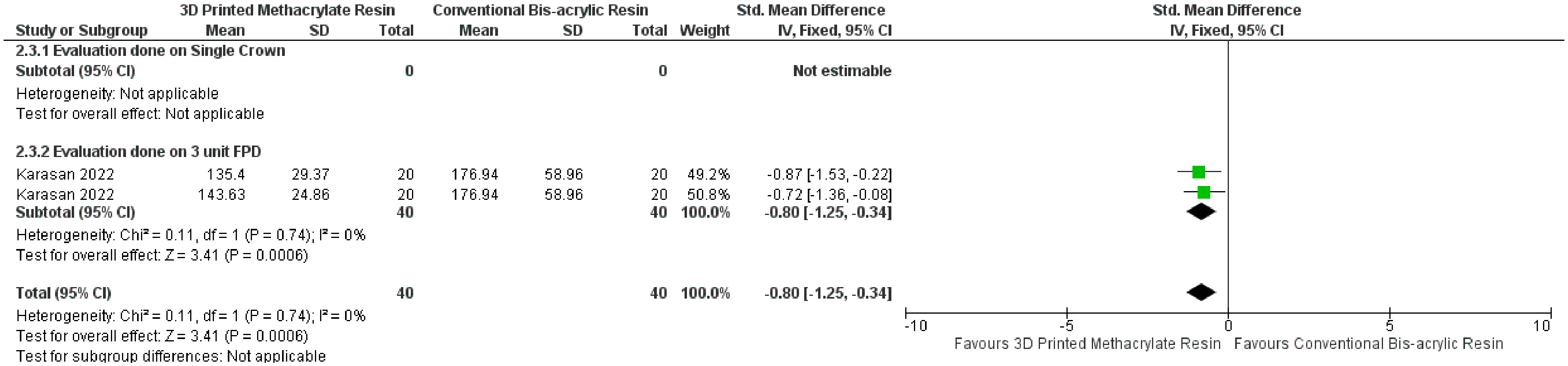
| | 3D Printed Methacrylate Resin | | | Conventional PMMA resin | | | | Std. Mean Difference |
|---|---|---|---|---|---|---|---|---|
| **Study or Subgroup** | **Mean** | **SD** | **Total** | **Mean** | **SD** | **Total** | **Weight** | **IV, Fixed, 95% CI** |
| **2.1.1 Evaluation done of Single Crown** | | | | | | | | |
| Aldahian 2021 | 211.87 | 17.8 | 10 | 395.89 | 80.33 | 10 | 26.9% | -3.03 [-4.40, -1.66] |
| Mohajeri 2021 | 91.4 | 36.07 | 14 | 51.23 | 21.7 | 14 | 73.1% | 1.31 [0.48, 2.14] |
| **Subtotal (95% CI)** | | | **24** | | | **24** | **100.0%** | **0.14 [-0.56, 0.85]** |
| Heterogeneity: Chi² = 28.35, df = 1 (P < 0.00001); I² = 96% | | | | | | | | |
| Test for overall effect: Z = 0.40 (P = 0.69) | | | | | | | | |
| **2.1.2 Evaluation done on 3 unit FPD** | | | | | | | | |
| **Subtotal (95% CI)** | | | **0** | | | **0** | | **Not estimable** |
| Heterogeneity: Not applicable | | | | | | | | |
| Test for overall effect: Not applicable | | | | | | | | |
| **Total (95% CI)** | | | **24** | | | **24** | **100.0%** | **0.14 [-0.56, 0.85]** |
| Heterogeneity: Chi² = 28.35, df = 1 (P < 0.00001); I² = 96% | | | | | | | | |
| Test for overall effect: Z = 0.40 (P = 0.69) | | | | | | | | |
| Test for subgroup differences: Not applicable | | | | | | | | |

**Figure 5.** Forest plot comparing the marginal discrepancy values of methacrylate-based 3D-printed provisional resins with conventional PMMA resins for evaluations performed on single crowns (2.1.1).



| | 3D Printed Methacrylate Resin | | | CAD CAM Milled PMMA Resin | | | | Std. Mean Difference |
|---|---|---|---|---|---|---|---|---|
| **Study or Subgroup** | **Mean** | **SD** | **Total** | **Mean** | **SD** | **Total** | **Weight** | **IV, Fixed, 95% CI** |
| **2.2.1 Evaluation done on Single Crown** | | | | | | | | |
| Aldahian 2021 | 211.87 | 17.8 | 10 | 244.95 | 19.65 | 10 | 12.1% | -1.69 [-2.74, -0.64] |
| Mohajeri 2021 | 91.4 | 36.07 | 14 | 75.28 | 22.14 | 14 | 23.5% | 0.52 [-0.23, 1.28] |
| **Subtotal (95% CI)** | | | **24** | | | **24** | **35.5%** | **-0.23 [-0.84, 0.39]** |
| Heterogeneity: Chi² = 11.19, df = 1 (P = 0.0008); I² = 91% | | | | | | | | |
| Test for overall effect: Z = 0.73 (P = 0.47) | | | | | | | | |
| **2.2.2 Evaluation done on 3 unit FPD** | | | | | | | | |
| Karasan 2022 | 143.63 | 24.86 | 20 | 100.46 | 65.76 | 20 | 31.7% | 0.85 [0.20, 1.50] |
| Karasan 2022 | 135.4 | 29.37 | 20 | 100.46 | 65.76 | 20 | 32.8% | 0.67 [0.03, 1.31] |
| **Subtotal (95% CI)** | | | **40** | | | **40** | **64.5%** | **0.76 [0.30, 1.22]** |
| Heterogeneity: Chi² = 0.15, df = 1 (P = 0.70); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 3.27 (P = 0.001) | | | | | | | | |
| **Total (95% CI)** | | | **64** | | | **64** | **100.0%** | **0.41 [0.04, 0.77]** |
| Heterogeneity: Chi² = 17.77, df = 3 (P = 0.0005); I² = 83% | | | | | | | | |
| Test for overall effect: Z = 2.19 (P = 0.03) | | | | | | | | |
| Test for subgroup differences: Chi² = 6.42, df = 1 (P = 0.01), I² = 84.4% | | | | | | | | |

**Figure 6.** Forest plot comparing the marginal discrepancy values of methacrylate-based 3D-printed provisional resins with CAD/CAM-milled PMMA resins for evaluations performed on single crowns (2.2.1) and on 3-unit FDPs (2.2.2).



| | 3D Printed Methacrylate Resin | | | Conventional Bis-acrylic Resin | | | | Std. Mean Difference |
|---|---|---|---|---|---|---|---|---|
| **Study or Subgroup** | **Mean** | **SD** | **Total** | **Mean** | **SD** | **Total** | **Weight** | **IV, Fixed, 95% CI** |
| **2.3.1 Evaluation done on Single Crown** | | | | | | | | |
| **Subtotal (95% CI)** | | | **0** | | | **0** | | **Not estimable** |
| Heterogeneity: Not applicable | | | | | | | | |
| Test for overall effect: Not applicable | | | | | | | | |
| **2.3.2 Evaluation done on 3 unit FPD** | | | | | | | | |
| Karasan 2022 | 135.4 | 29.37 | 20 | 176.94 | 58.96 | 20 | 49.2% | -0.87 [-1.53, -0.22] |
| Karasan 2022 | 143.63 | 24.86 | 20 | 176.94 | 58.96 | 20 | 50.8% | -0.72 [-1.36, -0.08] |
| **Subtotal (95% CI)** | | | **40** | | | **40** | **100.0%** | **-0.80 [-1.25, -0.34]** |
| Heterogeneity: $Chi^2 = 0.11$, df = 1 ($P = 0.74$); $I^2 = 0\%$ | | | | | | | | |
| Test for overall effect: $Z = 3.41$ ($P = 0.0006$) | | | | | | | | |
| **Total (95% CI)** | | | **40** | | | **40** | **100.0%** | **-0.80 [-1.25, -0.34]** |
| Heterogeneity: $Chi^2 = 0.11$, df = 1 ($P = 0.74$); $I^2 = 0\%$ | | | | | | | | |
| Test for overall effect: $Z = 3.41$ ($P = 0.0006$) | | | | | | | | |
| Test for subgroup differences: Not applicable | | | | | | | | |

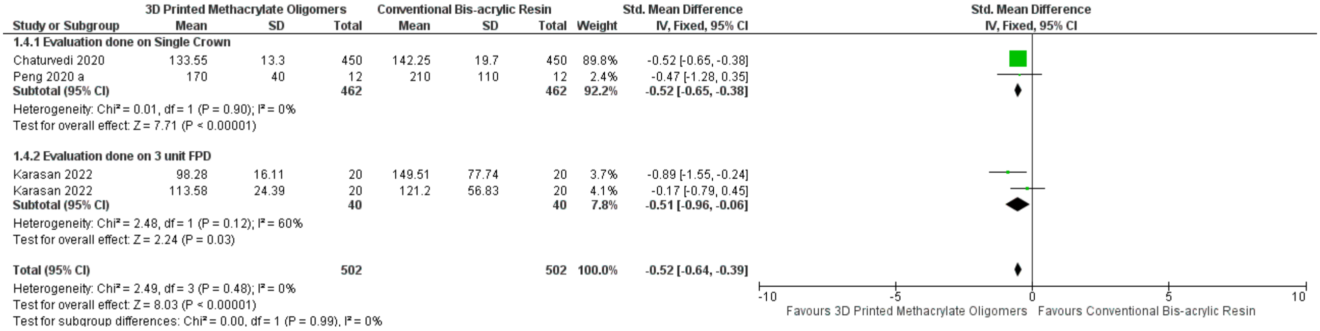
**Figure 7.** Forest plot comparing the marginal discrepancy values of methacrylate-based 3D-printed provisional resins with conventional bis-acrylic provisional resins for evaluations performed on 3-unit FDPs (2.3.2).

### 3.5.2. Comparing the Internal Discrepancy Values of 3D-Printed Methacrylate Oligomers

(i) Comparing the internal discrepancy values of 3D-printed methacrylate oligomers with conventional bis-acrylic provisional resin:

  (A) Evaluation performed on single crowns: Lower internal discrepancies were reported for 3D-printed methacrylate oligomers when compared to conventional bis-acrylic provisional resins [5,34] (Figure 8). The pooled SMD was 0.52 (−0.65 to −0.38) in favor of 3D-printed methacrylate oligomers and was statistically significant ($p < 0.05$).

  (B) Evaluation performed on three-unit FDPs: Karasan et al. [38] compared two different brands of 3D-printed methacrylate oligomers and reported lower internal discrepancies when compared to conventional bis-acrylic provisional resins (Figure 8). The pooled SMD was −0.51 (−0.96 to −0.06) in favor of 3D-printed methacrylate oligomers and was statistically significant ($p < 0.05$).



| | 3D Printed Methacrylate Oligomers | | | Conventional Bis-acrylic Resin | | | | Std. Mean Difference |
|---|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | IV, Fixed, 95% CI |
| **1.4.1 Evaluation done on Single Crown** | | | | | | | | |
| Chaturvedi 2020 | 133.55 | 13.3 | 450 | 142.25 | 19.7 | 450 | 89.8% | -0.52 [-0.65, -0.38] |
| Peng 2020 a | 170 | 40 | 12 | 210 | 110 | 12 | 2.4% | -0.47 [-1.28, 0.35] |
| **Subtotal (95% CI)** | | | **462** | | | **462** | **92.2%** | **-0.52 [-0.65, -0.38]** |
| Heterogeneity: Chi² = 0.01, df = 1 (P = 0.90); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 7.71 (P < 0.00001) | | | | | | | | |
| **1.4.2 Evaluation done on 3 unit FPD** | | | | | | | | |
| Karasan 2022 | 98.28 | 16.11 | 20 | 149.51 | 77.74 | 20 | 3.7% | -0.89 [-1.55, -0.24] |
| Karasan 2022 | 113.58 | 24.39 | 20 | 121.2 | 56.83 | 20 | 4.1% | -0.17 [-0.79, 0.45] |
| **Subtotal (95% CI)** | | | **40** | | | **40** | **7.8%** | **-0.51 [-0.96, -0.06]** |
| Heterogeneity: Chi² = 2.48, df = 1 (P = 0.12); I² = 60% | | | | | | | | |
| Test for overall effect: Z = 2.24 (P = 0.03) | | | | | | | | |
| **Total (95% CI)** | | | **502** | | | **502** | **100.0%** | **-0.52 [-0.64, -0.39]** |
| Heterogeneity: Chi² = 2.49, df = 3 (P = 0.48); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 8.03 (P < 0.00001) | | | | | | | | |
| Test for subgroup differences: Chi² = 0.00, df = 1 (P = 0.99), I² = 0% | | | | | | | | |

**Figure 8.** Forest plot comparing the internal discrepancy values of 3D-printed methacrylate oligomers with conventional bis-acrylic provisional resin for evaluations performed on single crowns (1.4.1) and on 3-unit FDPs (1.4.2). a: [5].

The overall SMD was −0.52 (−0.64 to −0.39) in favor of 3D-printed methacrylate oligomers over conventional bis-acrylic resin and was statistically significant ($p < 0.05$).

(ii) Comparing the internal discrepancy values of 3D-printed methacrylate oligomers with conventional PMMA resin:

  (A) Evaluation performed on single crowns: One study reported lower internal discrepancies for 3D-printed methacrylate oligomers when compared to conventional PMMA resin [25], whereas another study reported higher internal discrepancies [44].

(iii) Comparing the internal discrepancy values of 3D-printed methacrylate oligomers with CAD/CAM-milled PMMA provisional resins:

  (A) Evaluation performed on single crowns: When 3D-printed methacrylate oligomers were compared to CAD/CAM-milled PMMA provisional resins, three studies reported lower internal discrepancies [34,39,43], one study reported a higher internal discrepancy [5], and another reported the same internal discrepancy for both materials [25] (Figure 9).

  (B) Evaluation performed on three-unit FDPs: Karasan et al. [38] compared two different brands of 3D-printed methacrylate oligomers and reported lower internal discrepancies when compared to CAD/CAM-milled PMMA resins (Figure 9).

The overall SMD was −2.25 (−2.41 to −2.08) in favor of 3D-printed methacrylate oligomers over CAD/CAM-milled PMMA resin and was statistically significant ($p < 0.05$).

### 3.5.3. Comparing the Internal Discrepancy Values of Methacrylate-Based 3D-Printed Provisional Resins

(i) Comparing the internal discrepancy values of methacrylate-based 3D-printed provisional resins with conventional PMMA resins:

   - (A) Evaluation performed on single crowns: Aldahian et al. [40] reported lower internal discrepancies for methacrylate-based 3D-printed provisional resins when compared to conventional PMMA resins.

- (ii) Comparing the internal discrepancy values of methacrylate-based 3D-printed provisional resins with CAD/CAM-milled PMMA resins:
   - (A) Evaluation performed on single crowns: Aldahian et al. [40] reported lower internal discrepancies for methacrylate-based 3D-printed provisional resins when compared to CAD/CAM-milled PMMA resins.
   - (B) Evaluation performed on three-unit FDPs: Karasan et al. [38] compared two different brands of 3D-printed methacrylate resins and reported that one of them had lower internal discrepancies, whereas the other had higher internal discrepancies when compared to CAD/CAM-milled PMMA resins (Figure 10).

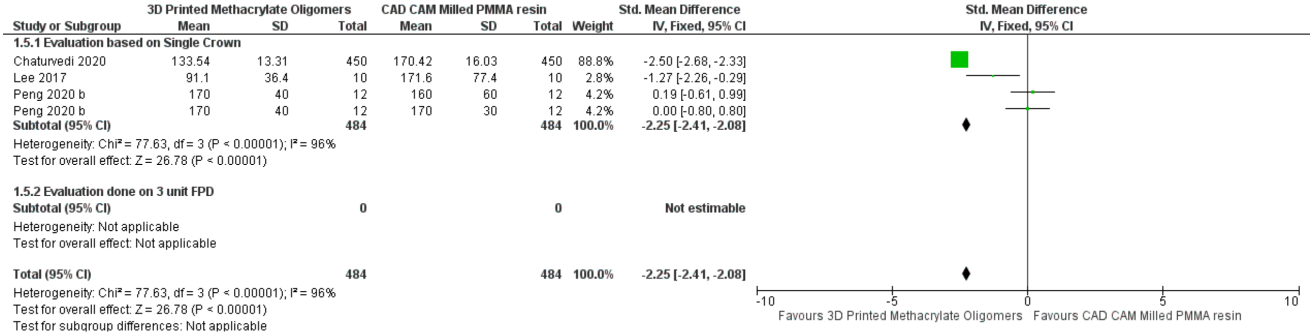


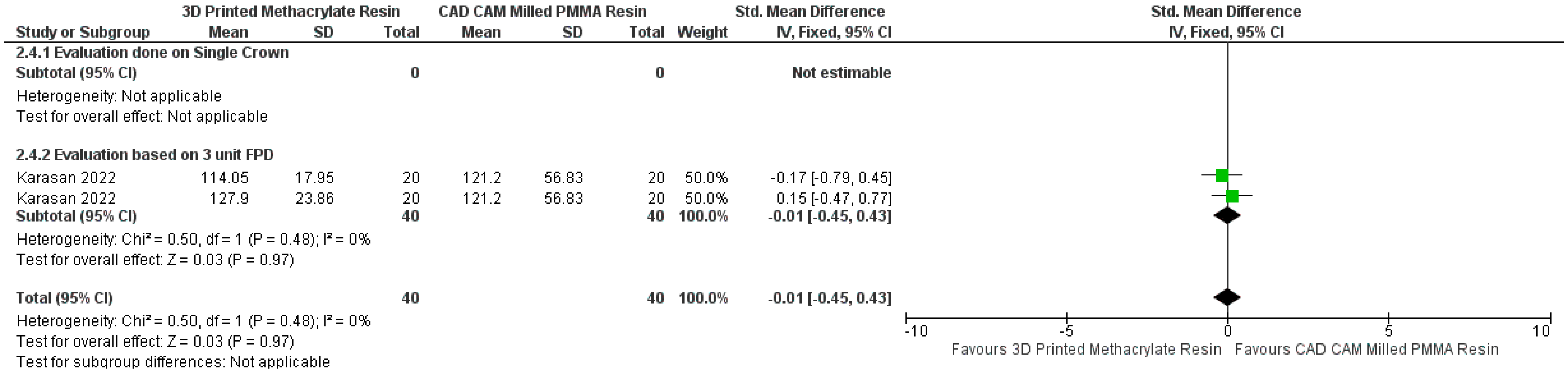
**Figure 9.** Forest plot comparing the internal discrepancy values of 3D-printed methacrylate oligomers with CAD/CAM-milled PMMA provisional resins for evaluations performed on single crowns (1.5.1) and on 3-unit FDPs (1.5.2). b: [25].

The overall SMD was −0.01 (−0.45 to 0.43) between 3D-printed methacrylate resin and CAD/CAM-milled PMMA resin and was statistically insignificant ($p > 0.05$).

- (iii) Comparing the internal discrepancy values of methacrylate-based 3D-printed provisional resins with conventional bis-acrylic provisional resins:
   - (A) Evaluation performed on three-unit FDPs: Karasan et al. [38] compared two different brands of 3D-printed methacrylate resins and reported that both had lower internal discrepancies when compared to conventional bis-acrylic provisional resins (Figure 11). The overall SMD was −0.49 (−0.94 to −0.04) in favor of 3D-printed methacrylate resin over conventional bis-acrylic resin and was statistically significant ($p < 0.05$).

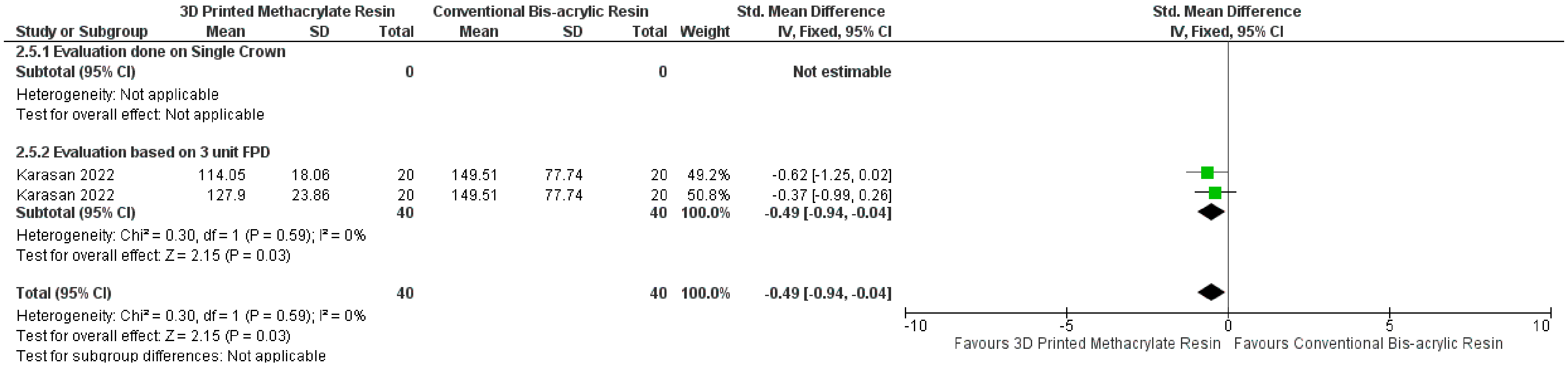
### 3.5.4. Comparing the Internal Discrepancy Values of 3D-Printed Hybrid-Composite-Based and Acrylic-Photopolymer-Based Provisional Resins

- (i) Comparing the internal discrepancy values of 3D-printed hybrid-composite-based provisional resins with CAD/CAM-milled PMMA resin:
   - (A) Evaluation performed on single crowns: Two studies compared the internal discrepancies of 3D-printed hybrid-composite-based and CAD/CAM-milled PMMA-based provisional resins. One study reported lower [10], while another reported higher [7] internal discrepancies for 3D-printed hybrid composites (Figure 12). The overall SMD was −3.68 (−4.47 to −2.88) in favor of 3D-printed hybrid composites over CAD/CAM-milled PMMA resin and was statistically significant ($p < 0.05$).



| | 3D Printed Methacrylate Resin | | | CAD CAM Milled PMMA Resin | | | | Std. Mean Difference |
|---|---|---|---|---|---|---|---|---|
| **Study or Subgroup** | **Mean** | **SD** | **Total** | **Mean** | **SD** | **Total** | **Weight** | **IV, Fixed, 95% CI** |
| **2.4.1 Evaluation done on Single Crown** | | | | | | | | |
| **Subtotal (95% CI)** | | | **0** | | | **0** | | **Not estimable** |
| Heterogeneity: Not applicable | | | | | | | | |
| Test for overall effect: Not applicable | | | | | | | | |
| **2.4.2 Evaluation based on 3 unit FPD** | | | | | | | | |
| Karasan 2022 | 114.05 | 17.95 | 20 | 121.2 | 56.83 | 20 | 50.0% | -0.17 [-0.79, 0.45] |
| Karasan 2022 | 127.9 | 23.86 | 20 | 121.2 | 56.83 | 20 | 50.0% | 0.15 [-0.47, 0.77] |
| **Subtotal (95% CI)** | | | **40** | | | **40** | **100.0%** | **-0.01 [-0.45, 0.43]** |
| Heterogeneity: Chi² = 0.50, df = 1 (P = 0.48); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 0.03 (P = 0.97) | | | | | | | | |
| **Total (95% CI)** | | | **40** | | | **40** | **100.0%** | **-0.01 [-0.45, 0.43]** |
| Heterogeneity: Chi² = 0.50, df = 1 (P = 0.48); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 0.03 (P = 0.97) | | | | | | | | |
| Test for subgroup differences: Not applicable | | | | | | | | |

**Figure 10.** Forest plot comparing the internal discrepancy values of methacrylate-based 3D-printed provisional resins with CAD/CAM-milled PMMA resins for evaluations performed on 3-unit FDPs (2.4.2).



| | 3D Printed Methacrylate Resin | | | Conventional Bis-acrylic Resin | | | | Std. Mean Difference |
|---|---|---|---|---|---|---|---|---|
| **Study or Subgroup** | **Mean** | **SD** | **Total** | **Mean** | **SD** | **Total** | **Weight** | **IV, Fixed, 95% CI** |
| **2.5.1 Evaluation done on Single Crown** | | | | | | | | |
| **Subtotal (95% CI)** | | | **0** | | | **0** | | **Not estimable** |
| Heterogeneity: Not applicable | | | | | | | | |
| Test for overall effect: Not applicable | | | | | | | | |
| **2.5.2 Evaluation based on 3 unit FPD** | | | | | | | | |
| Karasan 2022 | 114.05 | 18.06 | 20 | 149.51 | 77.74 | 20 | 49.2% | -0.62 [-1.25, 0.02] |
| Karasan 2022 | 127.9 | 23.86 | 20 | 149.51 | 77.74 | 20 | 50.8% | -0.37 [-0.99, 0.26] |
| **Subtotal (95% CI)** | | | **40** | | | **40** | **100.0%** | **-0.49 [-0.94, -0.04]** |
| Heterogeneity: Chi² = 0.30, df = 1 (P = 0.59); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 2.15 (P = 0.03) | | | | | | | | |
| **Total (95% CI)** | | | **40** | | | **40** | **100.0%** | **-0.49 [-0.94, -0.04]** |
| Heterogeneity: Chi² = 0.30, df = 1 (P = 0.59); I² = 0% | | | | | | | | |
| Test for overall effect: Z = 2.15 (P = 0.03) | | | | | | | | |
| Test for subgroup differences: Not applicable | | | | | | | | |

**Figure 11.** Forest plot comparing the internal discrepancy values of methacrylate-based 3D-printed provisional resins with conventional bis-acrylic provisional resins for evaluations performed on 3-unit FDPs (2.5.2).

(ii) Comparing the internal discrepancy values of 3D-printed composite-based provisional resins with conventional PMMA and bis-acrylic provisional resins:
   (A) Sampaio et al. [7] reported higher internal discrepancies for provisional crowns fabricated with 3D-printed composite resins when compared to those fabricated using conventional PMMA and bis-acrylic provisional resins.

(iii) Comparing the internal discrepancy values of 3D-printed acrylic photopolymer resins with CAD/CAM-milled PMMA resins:
   (A) Lee et al. [43] reported lower internal discrepancies for provisional crowns fabricated with 3D-printed acrylic photopolymer resins when compared to those fabricated using CAD/CAM-milled PMMA resins.

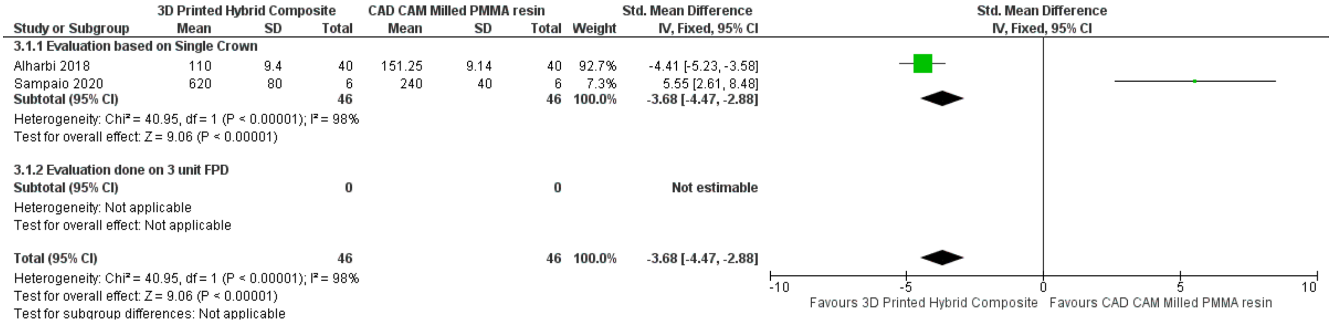


**Figure 12.** Forest plot comparing the internal discrepancy values of 3D-printed hybrid-composite-based provisional resins with CAD/CAM-milled PMMA resins for evaluations performed on single crowns (3.1.1).

## 4. Discussion

This systematic review included all of the published English literature comparing the internal adaptation and/or marginal fit of 3D-printed provisional crowns and FDPs with those fabricated using other provisional materials and techniques. To the best of our knowledge, this is the first review of its kind. A total of 16 in vitro studies were included in this research, of which 11 studies analyzed both marginal fit and internal adaptation, 3 studies analyzed only internal adaptation, and 2 studies analyzed only marginal fit of provisional crowns and FDPs. The outcomes of this review suggest that the internal adaptation and marginal fit of provisional restorations are affected by the types of provisional materials used and the techniques of fabrication. Therefore, the tested null hypothesis was rejected.

A well-fabricated provisional prosthesis should have a precise marginal fit in order to minimize the microleakage, protecting the pulp of the prepared tooth and minimizing bacterial accumulation at the margins of the restoration, thus preventing the inflammation of the soft tissues around the tooth and the implant-supported restorations [14,25–32,49]. Good internal adaptation is also vital for provisional restoration to be successful. Structural durability is affected by adaptation at the occlusal surface, whereas maintenance requirements are affected by the axial fit of the provisional crowns and FDPs [14,49].

In general, the majority (i.e., 8 out of 13) of the studies included in this review reported that marginal discrepancies were least with the provisional restorations fabricated by 3D printing when compared to those fabricated by CAD/CAM milling and conventional techniques [10,14,34,37–40,44]. In two studies, the marginal discrepancy reported for 3D-printed provisional crowns was equal to that of those fabricated by CAD/CAM milling [5,25], whereas in two studies, the 3D-printed provisional crowns displayed the greatest marginal discrepancy [35,41]. Overall, most of the studies reported that marginal discrepancies were highest in provisional restorations fabricated using conventional techniques and materials [10,14,34,36–40,44]. Even though there were differences in marginal discrepancies in provisional restorations fabricated using different materials and techniques, they were within the clinically acceptable limit of less than 120 μm for most of the studies [50,51] (in some studies, a maximum misfit of up to 200 µm was considered to be clinically permitted [36,43,52,53]).

Two studies [10,34] evaluated the effect of the type of finish line on the absolute marginal discrepancy of provisional crowns and reported the least marginal discrepancy with a rounded shoulder with a bevel finish line [10,34] and the highest marginal discrepancy with chamfer [10,34] and knife edge [10] finish lines. The high marginal discrepancy for the chamfer finish line could be due to the topography of the chamfer finish line having a curved axiogingival line angle, which can increase the chances of stair-stepping errors during the incremental layer pattern of buildup in 3D printing [10]. It was reported that the fabrication method of provisional restoration has more effect on the marginal fit as compared to the type of finish line [10,34].

When the internal adaptation of provisional crowns and FDPs was analyzed, 7 out of 13 studies reported minimal internal discrepancies for 3D-printed restorations [10,14,34,38–40,43], 4 for CAD/CAM-milled restorations [5,7,36,42], and 2 for conventionally fabricated restorations [35,44]. One study [25] reported similar internal discrepancies for 3D-printed and CAD/CAM-milled provisional crowns and FDPs. The mean occlusal discrepancy was reported to be greater than the mean intermarginal, axiogingival, and axio-occlusal discrepancies [14,34,39,43]. The higher occlusal discrepancy with CAD/CAM-milled provisional could be attributed to the limited size and angle of cutting tools and uneven surfaces on occlusal areas, leading to problems in milling the intaglio surface [23,35,43,44,54].

Conventional provisional resins exhibit high volumetric polymerization shrinkage (higher with PMMA as compared to acrylic-based composite resins) [55–58]. They also involve manual trimming of excess material and removal during the setting time, leading to distortion [36,40] and, thus, exhibiting poor marginal and internal adaptation when compared to CAD/CAM milling procedures, where the restoration is milled from a dense, pre-polymerized block by an automated machine so that there is no polymerization shrinkage [59–61]. When compared to 3D-printed provisional crowns and FDPs, CAD/CAM-milled provisional restorations had poor marginal and internal adaptation. In CAD/CAM milling, the manufacturing process is affected by the size of the milling bur and its range of cutting movement [10,14,43,62–64], whereas, in 3D printing, there is an incremental layering process, which reproduces details accurately and compensates for polymerization shrinkage [25,37,44,65]. Few studies have reported better marginal and internal fit for CAD/CAM-milled as compared to 3D-printed provisional restorations. This could be attributed to the different types of 3D printers and different printing settings used in these studies. The accuracy of 3D printed materials is influenced by the type of printer, layer thickness, number of layers, layer intensity, printer wavelength, total thickness, die-spacer thickness, arrangement of crowns, UV intensity, post-processing method, build angle, and number and placement of support structures [16,18,36,38,66–71]. Irrespective of the materials and method of fabrication, overall discrepancies were reported to be higher in three-unit FDPs when compared to single crowns. For conventional resins, this could be due to the magnified volumetric shrinkage and deformation in FDPs when compared to crowns due to the geometric shape of the prosthesis [14,36,57].

Two studies [7,35] measured the discrepancies after cementing the provisional restoration with luting cement; seven studies [34,36,37,39,41,42,44] used a non-cementation approach, and two studies [5,25] used both cementation and non-cementation approaches. Studies have reported that the process of placement and cementation of the prosthesis can lead to variations and may cause bias in the outcome [36,37,72]. The method of measuring the fit also affects the outcomes of the studies. Included studies have used different methods to measure the fit of the provisional restoration. These include silicone replica techniques, micro-CT, and cross-section techniques [5–7,10,14,25,34,35,42–44]. The cross-section technique is reported to cause errors in measurements due to some deformation during cross-sectioning [73] or due to operator dependency, resulting in sectioning in inconsistent planes [74]. In contrast, using micro-CT allows multiple and repeated measurements of critical spaces by producing 2D and 3D images [75–78].

The strengths of this systematic review are its detailed search strategy and systematic methodology to avoid bias during the selection of the studies. In order to avoid missing out on any relevant studies, all articles analyzing the fit and adaptation of the selected materials were subjected to the selection criteria.

To reduce the variability in the included studies and to make the systematic review more informative, the authors would like to add some suggestions:

1. Whenever possible, the researchers should keep measurement units constant.
2. Studies should use the same standardized protocol for specimen fabrication and testing (set by ISO or ADA).
3. Researchers should provide data in both graphical and tabular form as it is easier to extract data from tables. If this is not possible, then data should be provided as supplementary files, which can be accessed easily [79].

### *Limitations*

The studies included in this systematic review showed high data variability, which could be due to the different types of resins and techniques used in the fabrication of the provisional restorations. Due to this high data variability, most of the meta-analyses included only two studies. Qualitatively, a moderate-to-high level of methodology was employed by most of the included studies, but the risk of bias was high. Recommendations include using standard protocols for in vitro studies and, wherever possible, providing data in tabular forms (along with graphs) while reporting the results so that they can be easily utilized. Additionally, only marginal fit and internal adaptation were evaluated and compared in this systematic review and meta-analysis. Further systematic reviews could be planned to determine the effects of 3D-printing parameters on the properties of 3D-printed resins.

## 5. Conclusions

Based on our findings, the following conclusions can be drawn:

- Digitally fabricated provisional crowns and FDPs have superior marginal fit and internal adaptation when compared to manually fabricated ones.
- Provisional crowns and FDPs fabricated from 3D-printing resins have a superior marginal fit and internal adaptation when compared to CAD/CAM-milled and conventional provisional resins. Thus, they can be used as a dependable alternative to other resins.
- For all three fabrication techniques, the marginal and internal discrepancy values were within the clinically acceptable ranges.
- Various factors affect the marginal fit and internal adaptation of 3D-printed provisional restorations, including the type of 3D-printing technology, layer thickness, printing orientation, type of provisional resin, etc.
- To improve the quality of future studies, in vitro studies should focus on reducing bias by following the recommended blinding protocols.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/coatings12111777/s1, Table S1: Search terms and strategy for the electronic databases; Table S2: PRISMA 2020 Main Checklist; Table S3: PRIMSA Abstract Checklist.

**Author Contributions:** Conceptualization, S.J., M.E.S., M.H.D.A.W. and A.A.; methodology, S.J., M.E.S., M.H.D.A.W., A.A., H.A., S.M.A., N.M.A., S.S.A., S.A., A.K.A. and M.M.G.; software, S.G.G., N.M.A., A.H.A., M.J., A.A.A., S.A., A.K.A. and M.M.G.; validation, S.J., M.E.S., S.M.A. and A.A.A.; formal analysis, S.J., H.A., S.G.G. and M.J.; investigation, S.J., A.A., A.H.A., S.S.A., S.A., A.K.A. and M.M.G.; resources, S.M.A., A.A.A., S.S.A., S.A., A.K.A. and M.M.G.; data curation, S.J., M.H.D.A.W., S.G.G., N.M.A. and M.J.; writing—original draft preparation, S.J., M.E.S., M.H.D.A.W., A.A., H.A., S.M.A., N.M.A. and A.H.A.; writing—review and editing, S.J., M.E.S., M.H.D.A.W., A.A., H.A., S.G.G., S.M.A., N.M.A., A.H.A., M.J., A.A.A., S.S.A., S.A., A.K.A. and M.M.G.; visualization, S.J., S.G.G. and

M.J.; supervision, M.E.S., S.J., and S.M.A.; project administration, M.E.S., S.J., H.A., N.M.A., A.H.A., A.A.A. and S.S.A. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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