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# Patient satisfaction with 3D-printed versus conventionally fabricated dental prostheses: a systematic review and meta-analysis

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## ABSTRACT

**Background:** Tooth loss compromises mastication, speech, esthetics, and oral health-related quality of life. Although three-dimensional (3D) printing may improve prosthesis reproducibility, shorten manufacturing time, and reduce clinical visits, whether these advantages increase patient satisfaction remains uncertain. **Objective:** To compare patient satisfaction with 3D-printed versus conventionally fabricated dental prostheses. **Methods:** This systematic review and meta-analysis included randomized clinical trials identified in PubMed/MEDLINE, Scopus, Web of Science, and Embase from database inception to February 2025, without language or publication-year restrictions. The protocol was registered in PROSPERO (CRD42025648057), and the review followed PRISMA 2020. Two reviewers independently performed study selection and data extraction. Risk of bias was assessed using Cochrane RoB 2, and certainty of evidence was evaluated with GRADE. Random-effects meta-analysis was conducted using standardized mean differences (SMDs). **Results:** Of 121 records identified, 18 studies met the eligibility criteria, and 10 contributed data to the meta-analysis. The pooled estimate showed no statistically significant difference in patient satisfaction between 3D-printed and conventionally fabricated prostheses (SMD = 0.03; 95% CI: –0.94 to 1.01; p = 0.94), with high heterogeneity ($I^2$ = 90%). Subgroup analyses of complete dentures and implant-supported prostheses also showed no significant differences. The certainty of evidence was low. **Conclusions:** Current evidence does not demonstrate superiority of either fabrication method for patient satisfaction. Clinical selection should therefore consider prosthesis type, fit, function, workflow requirements, and patient preferences.

**Keywords:** Patient Satisfaction; Printing, Three-Dimensional; Dental Prosthesis; Denture, Complete; Dental Prosthesis, Implant-Supported.

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## Introduction

Tooth loss, partial edentulism, and complete edentulism remain clinically relevant oral health conditions because they can compromise mastication, speech, facial appearance, and oral health-related quality of life [1–3]. Prosthetic rehabilitation is therefore essential for restoring oral function and improving the physical and psychosocial well-being of affected patients. Nevertheless, the success of dental prostheses should not be assessed exclusively through technical or biological outcomes. Patient satisfaction is a multidimensional patient-reported outcome influenced by comfort, retention, stability, esthetics, phonetics, masticatory performance, ease of cleaning, previous expectations, and the overall treatment experience [4,5]. Accordingly, evaluating satisfaction is essential for determining whether a prosthetic treatment provides benefits that are meaningful from the patient's perspective.

Conventionally fabricated dental prostheses have been used as the standard therapeutic approach for decades; however, their production requires multiple clinical and laboratory procedures and may be affected by operator-dependent variability. The incorporation of computer-aided design and manufacturing and three-dimensional (3D) printing has progressively transformed prosthodontic workflows by enabling the additive fabrication of individualized prostheses from digital designs. Potential advantages include greater standardization and reproducibility, shorter production times, fewer clinical appointments, and the possibility of reproducing lost or damaged prostheses from stored digital records [6–8]. However, randomized clinical trials have reported inconsistent patient-reported outcomes. Kang et al. found no significant difference in overall satisfaction between digitally and conventionally fabricated complete dentures, although conventional dentures showed better masticatory efficiency and pronunciation [9]. Nabil et al. reported comparable overall satisfaction and masticatory performance between conventional and 3D-printed implant overdentures, but conventional prostheses received higher esthetic scores [10]. Iwaki et al. observed no significant differences in patient satisfaction or oral health-related quality of life [11], whereas Ohara et al. found greater satisfaction with conventional dentures in specific domains, including stability, comfort, pronunciation, and ease of cleaning [12]. Thus, it remains unclear whether the technical and operational advantages of 3D printing result in clinically meaningful improvements in patient satisfaction.

Clarifying this uncertainty has clinical, methodological, and public health relevance. In complete denture treatment, adaptation to the supporting tissues, peripheral sealing, fit, and retention can directly influence comfort, speech, mastication, and treatment acceptance [13,14]. In implant-supported rehabilitation, prosthetic support and stability may improve masticatory function and patient perception independently of the manufacturing method [15]. From a public health perspective, 3D printing could facilitate standardized production, shorten fabrication times, and enable rapid replacement of dental prostheses, particularly in settings with limited access to specialized laboratory services [16]. Nevertheless, its implementation requires adequate technological infrastructure, trained personnel, validated materials, and standardized quality-control procedures. Furthermore, differences among studies regarding prosthesis type, supporting structures, manufacturing protocols, measurement instruments, adaptation periods, and follow-up duration may contribute to the variability of the available evidence. A systematic synthesis is therefore required to distinguish the effect of the fabrication method from other clinical and methodological factors that may influence patient satisfaction.

The objective of this systematic review and meta-analysis was to compare patient satisfaction with 3D-printed versus conventionally fabricated dental prostheses and to determine whether the findings differed according to the type of prosthetic rehabilitation, particularly complete dentures and implant-supported prostheses. This study is scientifically and clinically justified by the need to synthesize the available randomized evidence, assess its risk of bias and certainty, and clarify whether additive manufacturing provides patient-perceived benefits beyond its technical and operational advantages. The findings may support evidence-based prosthodontic decision-making by integrating patient-reported outcomes with clinical requirements, manufacturing efficiency, accessibility, and individual patient preferences.

## Materials and methods

### Study Design and Protocol Registration

This study was conducted as a systematic review and meta-analysis of randomized controlled trials comparing patient satisfaction with three-dimensional (3D)-printed and conventionally fabricated dental prostheses. The protocol was prospectively registered in the International

Prospective Register of Systematic Reviews (PROSPERO; CRD42025648057). The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement [17].

### Eligibility Criteria

Eligibility criteria were defined according to the population, intervention, comparator, outcome, and study design framework. The population comprised patients requiring prosthetic dental rehabilitation. The intervention consisted of dental prostheses fabricated using 3D-printing technology, whereas the comparator consisted of dental prostheses manufactured using conventional clinical and laboratory techniques. The primary outcome was patient satisfaction with the prosthetic rehabilitation.

Studies were included if they: (1) were randomized controlled trials with parallel-group or crossover designs; (2) directly compared 3D-printed and conventionally fabricated dental prostheses; and (3) reported quantitative data on overall patient satisfaction or specific satisfaction domains, including comfort, retention, stability, esthetics, phonetics, masticatory function, ease of cleaning, or adaptation. No restrictions were applied regarding language or year of publication.

Observational studies, including cohort, case-control, and cross-sectional studies, were excluded. Case reports, case series, in vitro studies, conference abstracts, editorials, letters to the editor, brief communications, and studies that did not provide extractable patient-satisfaction data were also excluded.

No sample-size calculation or probabilistic sampling method was applicable because this study sought to include all randomized controlled trials that fulfilled the predefined eligibility criteria. The number of included studies and participants was determined by the systematic search and selection process.

### Information Sources and Search Strategy

A comprehensive electronic search was conducted in PubMed/MEDLINE, Scopus, Web of Science, and Embase from database inception to February 2025. No restrictions were imposed regarding language or publication year.

The search strategies combined Medical Subject Headings, database-specific controlled vocabulary, and free-text terms related to patient satisfaction, dental prostheses, complete dentures, implant-supported prostheses, three-dimensional printing, additive manufacturing, digital fabrication, conventional fabrication, and randomized controlled trials. Boolean operators were adapted to the syntax and indexing requirements of each database. The complete search strategy for each database is presented in the supplementary material.

### Study Selection

All records retrieved from the electronic searches were imported into Rayyan® systematic review software for reference organization, duplicate identification, and screening.

Two reviewers independently screened the titles and abstracts according to the predefined eligibility criteria. Potentially eligible records were subsequently evaluated in full text by the same reviewers. Studies meeting all eligibility criteria were included in the qualitative synthesis, whereas those reporting sufficient numerical data were considered for quantitative synthesis.

Disagreements between reviewers were resolved through discussion and consensus. When consensus could not be reached, a third reviewer assessed the study and made the final decision. Reasons for excluding studies during full-text assessment were recorded. The identification, screening, eligibility, and inclusion processes were summarized using a PRISMA 2020 flow diagram.

### Data Extraction

Two reviewers independently extracted the relevant information using a standardized data collection form developed in Microsoft Excel version 2021. Data were obtained from the methods, results, discussion, and conclusions sections of the included studies.

The extracted information included author, publication year, country, study design, sample size, participant characteristics, type of prosthetic rehabilitation, intervention, comparator, manufacturing technique, prosthetic material, follow-up duration, satisfaction domains, measurement scale or questionnaire, and numerical data required for quantitative synthesis.

The systematic review did not develop or administer a new measurement instrument. Patient satisfaction data were extracted according to the instruments used by the original randomized controlled trials, including visual analog scales, structured questionnaires, or other patient-reported rating scales. The scoring range, direction of interpretation, evaluated domains, and reported validity or reliability information were recorded when these data were provided by the original investigators.

Disagreements during data extraction were resolved by consensus or through consultation with a third reviewer.

### Risk of Bias Assessment and Certainty of Evidence

Two reviewers independently assessed the risk of bias of the included randomized controlled trials using the Cochrane Risk of Bias 2 tool. The evaluated domains comprised bias arising from the randomization process, bias due to deviations from the intended interventions, bias due to missing outcome data, bias in the measurement of the outcome, and bias in the selection of the reported result.

Each domain and the overall risk-of-bias judgment were classified as low risk of bias, some concerns, or high risk of bias. Disagreements were resolved through discussion and consensus or, when necessary, consultation with a third reviewer.

The certainty of the evidence was evaluated using the Grading of Recommendations Assessment, Development and Evaluation approach. The certainty assessment considered risk of bias, inconsistency, indirectness, imprecision, and other factors relevant to the body of evidence. The certainty of evidence was classified as high, moderate, low, or very low.

### Statistical Analysis

Patient satisfaction was analyzed as a continuous outcome. Because the included trials used different scales and scoring systems, standardized mean differences with 95% confidence intervals were calculated. A random-effects model and the inverse-variance method were applied because clinical and methodological heterogeneity was anticipated among studies regarding prosthesis type, materials, measurement instruments, and follow-up duration.

Statistical heterogeneity was assessed using the Chi-square Q test and the $I^2$ statistic. $I^2$ values were interpreted as low between 0% and 30%, moderate above 30% and up to 60%, and high when greater than 60%.

Subgroup analyses were conducted according to the type of prosthetic rehabilitation, particularly complete dentures and implant-supported prostheses. Differences in follow-up duration were considered when interpreting clinical and statistical heterogeneity. All statistical tests were two-sided, and a p-value $< 0.05$ was considered statistically significant. Data organization and management were performed using Microsoft Excel version 2021.

### Ethical considerations

The study protocol was evaluated by the Bioethics Committee of Universidad Privada Antenor Orrego. Because this systematic review and meta-analysis exclusively analyzed aggregate data from previously published studies and did not involve direct contact with participants, clinical interventions, or access to identifiable personal information, individual informed consent was not applicable. The study adhered to the ethical principles established in the Declaration of Helsinki [18].

## Results

*Study Selection*

The database search identified 121 records: 10 from PubMed/MEDLINE, 79 from Scopus, 7 from Web of Science, and 25 from Embase. After removing 35 duplicate records, 86 titles and abstracts were screened, of which 57 were excluded because they did not meet the eligibility criteria. Twenty-nine reports were sought for retrieval, but seven could not be obtained. Subsequently, 22 full-text reports were assessed for eligibility. Four reports were excluded: three because of incomplete or insufficient data and one because the randomized clinical trial was still in progress. Finally, 18 studies were included in the systematic review, and 10 provided sufficient data for quantitative synthesis (Figure 1).

*Characteristics of Included Studies*

The 18 included studies were published between 2012 and 2025. Individual sample sizes ranged from 8 to 76 participants. The studies evaluated patients with different prosthetic rehabilitation needs, ranging from partial tooth loss to complete edentulism. The interventions included 3D-printed temporary or provisional crowns, fixed dental prostheses, complete dentures, implant-supported prostheses, bars, and overdentures, which were compared with equivalent prostheses fabricated using conventional techniques.

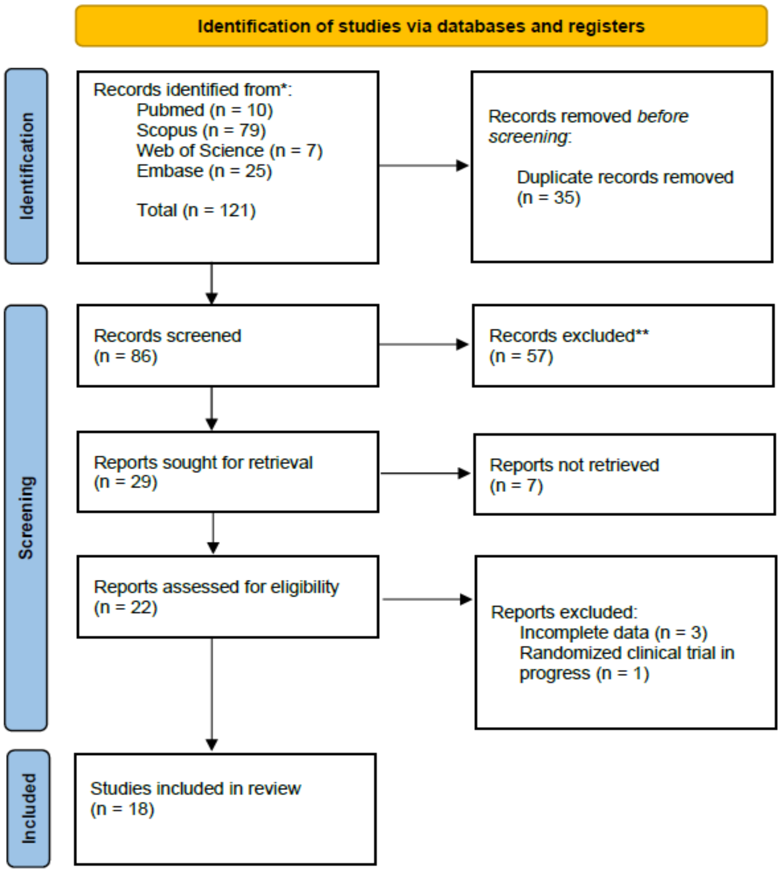



**Figure 1.** PRISMA 2020 flow diagram of the study selection process.

Patient satisfaction was assessed using visual analog scales, structured satisfaction scales, the Oral Health Impact Profile for Edentulous Adults, the McGill Denture Satisfaction Questionnaire, and modified United States Public Health Service criteria. The evaluated domains included overall satisfaction, comfort, stability, esthetics, phonetics, masticatory function, ease of cleaning, adaptation, and perception of the clinical procedure. Follow-up periods ranged from 48 hours to 2 years (Table 1).

*Risk of Bias*

The overall risk-of-bias assessment showed that most studies were classified as having a low risk of bias in random sequence generation and incomplete outcome data. Allocation concealment presented predominantly low-risk judgments, although some studies were classified as unclear or high risk. Greater variability was observed in the blinding of participants and personnel, with several studies presenting unclear or high-risk judgments. Blinding of outcome assessment was predominantly classified as low risk, whereas selective reporting and other potential sources of bias were frequently judged as unclear because of insufficient methodological information (Figure 2).

The assessment of individual studies showed differences across methodological domains. Most trials presented low-risk judgments for sequence generation and management of incomplete data. However, Al-Kaff and Al Hamad and Inokoshi et al. showed high-risk judgments in allocation concealment or blinding-related domains. Some studies, including Ohara et al. and Peñarrocha et al., presented unclear judgments regarding selective reporting or the completeness of the reported information (Figure 3).

*Quantitative Synthesis*

*Overall Patient Satisfaction*

Ten studies were included in the meta-analysis of patient satisfaction. Because the studies used different instruments and scoring systems, the standardized mean difference was used as the effect measure. The random-effects model produced a pooled standardized mean difference of 0.03 (95% CI: −0.94 to 1.01; $p = 0.94$). Statistical heterogeneity was high (Chi-square = 91.19; $df = 9$; $p < 0.00001$; $I^2 = 90\%$) (Figure 4).

**Table 1.** Characteristics of included randomized controlled trials

| Author | Year | Country | Study Design | Sample Size (n) | Intervention | Control | Patient Characteristics | Clinical Parameters | Satisfaction assessment | Follow-up | Main Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cao et al. [19] | 2024 | China | Randomized clinical trial | 30 | 3D-printed temporary crowns | Conventionally fabricated temporary crowns | Patients with posterior tooth loss undergoing implant surgery | Placement time, prosthesis accuracy, and patient satisfaction | Patient satisfaction scale | 1 and 6 months | The 3D-printed temporary crowns showed greater accuracy, shorter placement time, and higher patient satisfaction. |
| de Souza et al. [20] | 2024 | Brazil | Randomized clinical trial | 33 | 3D-printed provisional crowns | Conventional PMMA provisional crowns | Patients with anterior dental implants requiring provisional crowns | Fracture rate, color variation, operating time, and patient satisfaction | Visual analog scale | Until placement of the definitive prosthesis | No statistically significant difference in patient satisfaction was found between groups (p > 0.05). |
| Deng et al. [21] | 2023 | China | Pilot clinical trial | 20 | Digital complete dentures | Conventional complete dentures | Edentulous patients requiring complete dentures | Patient satisfaction, occlusal stability, and operating time | Patient satisfaction scale | Until placement of the definitive prosthesis | No statistically significant differences in satisfaction outcomes were found between groups (p > 0.05). |
| Al-Kaffy and Al Hamad [22] | 2024 | Jordan | Randomized clinical trial | 40 | 3D-printed complete dentures fabricated using intraoral scanning | Conventionally fabricated complete dentures | Edentulous patients requiring complete dentures | Fabrication time, fit, comfort, and patient satisfaction | Arabic version of the Oral Health Impact Profile for Edentulous Adults, using a 5-point Likert scale | 48 hours and 4 weeks | No statistically significant difference in patient satisfaction was found between groups (p = 0.11). |
| Almufleh et al. [23] | 2018 | Saudi Arabia | Randomized clinical trial | 50 | 3D-printed dental prostheses | Conventionally fabricated dental prostheses | Partially edentulous patients | Patient satisfaction, occlusal adjustment, and adaptation time | Visual analog scale | 1, 2, and 4 weeks | Statistically significant between-group differences were reported in overall satisfaction, comfort, stability, ease of cleaning, and the ability to speak and chew (p < 0.05). |

**Abbreviations:** 3D = three-dimensional ; CAD/CAM = computer-aided design and computer-aided manufacturing ; Co-Cr = cobalt-chromium ; MDSQ = McGill Denture Satisfaction Questionnaire; OHIP-EDENT = Oral Health Impact Profile for Edentulous Adults ; PMMA = polymethyl methacrylate ; USPHS = United States Public Health Service; VAS = visual analog scale.

**Table 1.** Characteristics of included randomized controlled trials (continued)

| Author | Year | Country | Study Design | Sample Size (n) | Intervention | Control | Patient Characteristics | Clinical Parameters | Satisfaction assessment | Follow-up | Main Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Badr et al. [24] | 2024 | Egypt | Randomized clinical trial | 20 | 3D-printed cobalt-chromium bar fabricated using CAD/CAM technology. | Conventional cobalt-chromium bar fabricated using casting techniques. | Completely edentulous patients in the maxilla and mandible. | Patient satisfaction, functionality, and evaluation time. | OHIP-EDENT-19 questionnaire | 6 and 12 months | No statistically significant difference in total satisfaction was found between groups at 12 months. |
| Batisse et al. [25] | 2014 | France | Randomized, prospective, double-blind crossover clinical trial | 16 | All-ceramic crowns fabricated using CAD/CAM technology. | Conventionally fabricated metal-ceramic crowns. | Partially edentulous patients in the anterior maxillary region. | Patient satisfaction, esthetics, and function. | Patient evaluation questionnaire using a 0–10 visual analog scale | 2 weeks | Patient satisfaction differed significantly between all-ceramic CAD/CAM crowns and metal-ceramic crowns ($p < 0.001$). |
| Gintaute et al. [26] | 2023 | witzerland | Randomized, double-blind crossover clinical trial | 20 | 3D-printed fixed dental prostheses. | Conventionally fabricated fixed dental prostheses. | Edentulous adults. | Patient satisfaction and perception of the impression procedure. | Visual analog scale | 1 month | No statistically significant difference in overall satisfaction was found between groups ($p = 0.876$). |
| Inokoshi et al.[27] | 2012 | Japan | Comparative clinical trial | 20 | 3D-printed complete dentures. | Conventionally fabricated complete dentures. | Edentulous adults. | Edentulous adults. | Visual analog scale. | 1 week | No statistically significant difference in overall satisfaction was found between prostheses ($p > 0.05$). |
| Kang et al. [9] | 2024 | South Korea | Randomized crossover clinical trial | 8 | Digital complete dentures fabricated from intraoral scans. | Conventionally fabricated complete dentures. | Completely edentulous patients. | Patient satisfaction and masticatory efficiency. | Visual analog scale | 1 and 2 months | No statistically significant difference in overall satisfaction was found for maxillary ($p = 0.172$) or mandibular dentures ($p = 0.161$). |

**Abbreviations:** 3D = three-dimensional ; CAD/CAM = computer-aided design and computer-aided manufacturing ; Co-Cr = cobalt-chromium ; MDSQ = McGill Denture Satisfaction Questionnaire; OHIP-EDENT = Oral Health Impact Profile for Edentulous Adults ; PMMA = polymethyl methacrylate ; USPHS = United States Public Health Service; VAS = visual analog scale.

**Table 1.** Characteristics of included randomized controlled trials (continued)

| Author | Year | Country | Study Design | Sample Size (n) | Intervention | Control | Patient Characteristics | Clinical Parameters | Satisfaction assessment | Follow-up | Main Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Kunavisarut et al. [28] | 2022 | Thailand | Randomized clinical trial | 20 | Implant-supported crowns fabricated through a digital workflow using an intraoral scanner | Conventionally fabricated provisional crowns | Partially edentulous patients | Patient satisfaction and perception of the impression procedure | Visual analog scale | 1 week | No statistically significant difference in satisfaction was found between groups ($p > 0.05$). |
| Magano et al. [29] | 2018 | Italy | Controlled clinical trial | 50 | Digitally designed crowns produced using intraoral scanning and CAD/CAM fabrication | Conventionally fabricated crowns | Partially edentulous patients | Patient satisfaction and restoration success | Visual analog scale | 1 year | No statistically significant difference in overall satisfaction was found between groups ($p > 0.05$). |
| Mühlemann et al. [30] | 2020 | Switzerland | Randomized clinical trial | 76 | Crowns fabricated using CAD/CAM technology | Conventionally fabricated crowns | Edentulous patients | Patient satisfaction and peri-implant tissue integrity | Modified United States Public Health Service criteria | 1 and 2 years | No statistically significant difference in satisfaction was found between CAD/CAM and conventional crowns ($p = 0.26$). |
| Nabil et al. [10] | 2024 | Egypt | Randomized crossover clinical trial | 32 | 3D-printed overdentures | Conventionally fabricated heat-polymerized overdentures | Mandibular edentulous patients | Patient satisfaction and masticatory efficiency | McGill Denture Satisfaction Questionnaire | 2 weeks, 3 months, and 6 months | No statistically significant difference in overall satisfaction was found between the 3D-printed and conventional overdentures ($p = 0.262$). |
| Ohara et al. [12] | 2022 | Japan | Randomized crossover clinical trial | 40 | 3D-printed digital complete dentures | Conventionally fabricated complete dentures | Maxillary and mandibular edentulous patients | Patient satisfaction and oral health-related quality of life | Visual analog scale | 3 and 6 months | Overall satisfaction was significantly lower with 3D-printed dentures ($p = 0.016$). |

**Abbreviations:** 3D = three-dimensional ; CAD/CAM = computer-aided design and computer-aided manufacturing ; Co-Cr = cobalt-chromium ; MDSQ = McGill Denture Satisfaction Questionnaire; OHIP-EDENT = Oral Health Impact Profile for Edentulous Adults ; PMMA = polymethyl methacrylate ; USPHS = United States Public Health Service; VAS = visual analog scale.

**Table 1.** Characteristics of included randomized controlled trials (continued)

| Author | Year | Country | Study Design | Sample Size (n) | Intervention | Control | Patient Characteristics | Clinical Parameters | Satisfaction assessment | Follow-up | Main Findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Peñarrocha et al. [31] | 2017 | Spain | Randomized pilot clinical trial | 18 | CAD/CAM implant-supported complete prostheses | Conventionally fabricated implant-supported complete prostheses | Edentulous patients | Patient satisfaction and marginal bone loss | Visual analog scale | 1 year | Patient satisfaction was significantly higher in the digital prosthesis group than in the conventional group ($p = 0.028$). |
| Van de Winkel et al. [32] | 2025 | The Netherlands | Randomized crossover clinical trial | 36 | 3D-printed overdentures | Conventionally fabricated overdentures | Maxillary and mandibular edentulous patients with dental implants | Patient satisfaction and oral health-related quality of life | Visual analog scale | 1 year | No statistically significant difference in satisfaction was found between 3D-printed and conventional prostheses ($p > 0.05$). |
| Iwaki et al. [11] | 2024 | Japan | Randomized crossover clinical trial | 18 | 3D-printed complete dentures | Conventionally fabricated complete dentures | Completely edentulous adults | Patient satisfaction and oral health-related quality of life | Visual analog scale | 1 month | No statistically significant difference in patient satisfaction was found between the two prosthesis |

**Abbreviations:** 3D = three-dimensional ; CAD/CAM = computer-aided design and computer-aided manufacturing ; Co-Cr = cobalt-chromium ; MDSQ = McGill Denture Satisfaction Questionnaire; OHIP-EDENT = Oral Health Impact Profile for Edentulous Adults ; PMMA = polymethyl methacrylate ; USPHS = United States Public Health Service; VAS = visual analog scale.

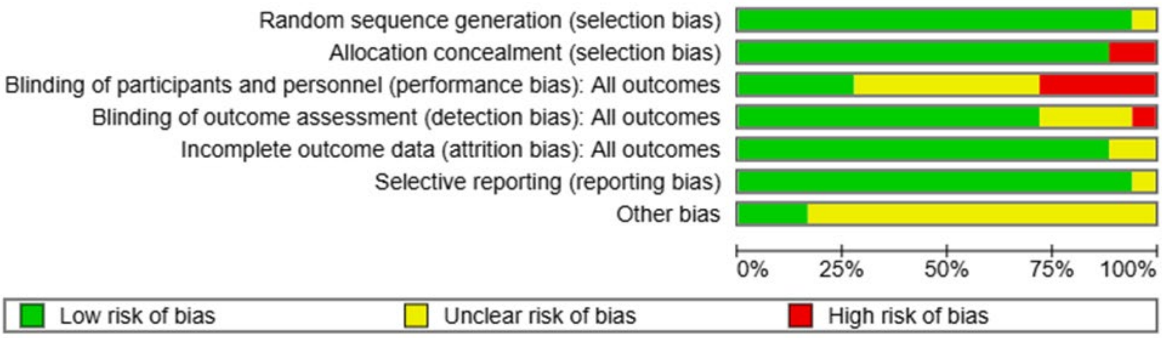



**Figure 2.** Overall risk-of-bias assessment across the included studies.

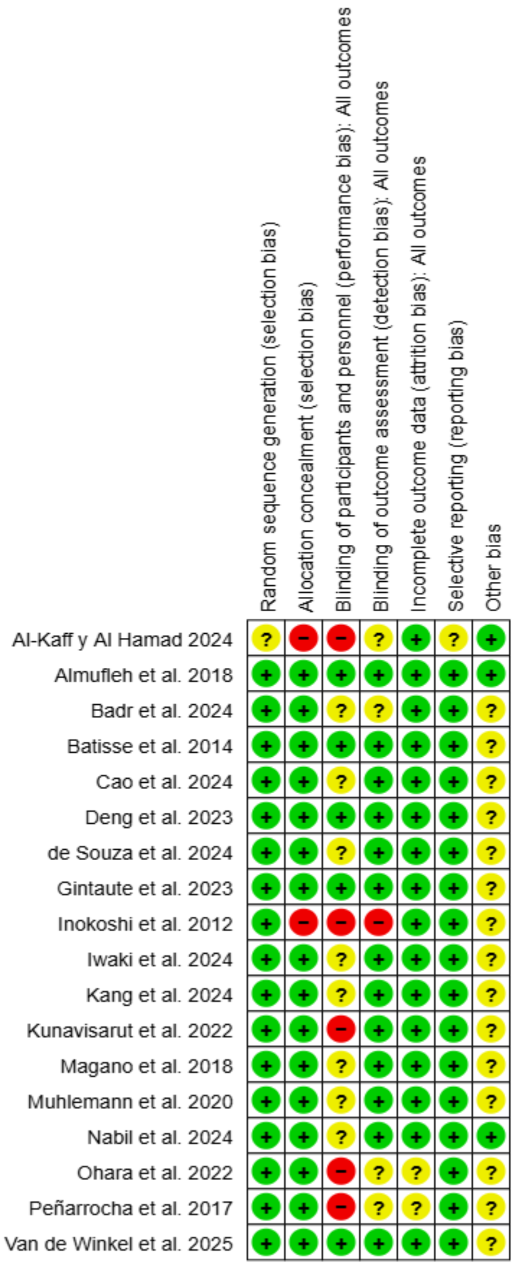



**Figure 3.** Risk-of-bias assessment for individual included studies.

*Subgroup Analysis According to Prosthesis Type*

Five studies evaluating complete dentures were included in the first subgroup. The pooled standardized mean difference was −0.28 (95% CI: −2.10 to 1.54; $p = 0.66$), with high statistical heterogeneity ($I^2 = 91\%$).

The subgroup of implant-supported prostheses also included five studies and produced a pooled standardized mean difference of 0.34 (95% CI: −1.33 to 2.02; $p = 0.57$), with high heterogeneity ($I^2 = 91\%$). The test for subgroup differences showed no statistically significant difference between complete dentures and implant-supported prostheses (Chi-square = 0.50; df = 1; $p = 0.48$; $I^2 = 0\%$) (Figure 5).

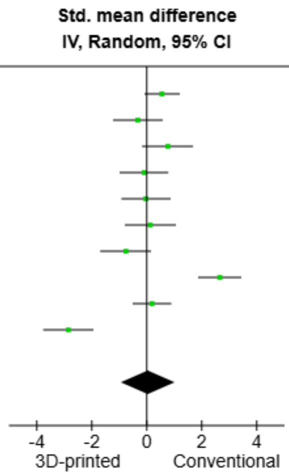
*Certainty of the Evidence*

The certainty of the evidence for patient satisfaction was rated as low according to the GRADE approach. The assessment included 10 randomized clinical trials and 280 observations incorporated into the quantitative synthesis. The certainty was downgraded because of substantial inconsistency among study results, clinical and methodological variability, small sample sizes, and wide confidence intervals (Table 2).

## Discussion

This systematic review included 18 eligible clinical trials, of which 10 contributed data to the quantitative synthesis. The pooled analysis showed no statistically significant difference in patient satisfaction between 3D-printed and conventionally fabricated dental prostheses (SMD = 0.03; 95% CI: −0.94 to 1.01; $p = 0.94$). However, this finding should not be interpreted as evidence of equivalence because the confidence interval was wide, statistical heterogeneity was substantial ($I^2 = 90\%$), and the certainty of the evidence was rated as low.

| | 3D-printed | | | Conventional | | | | Std. mean difference |
|---|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | IV, Random, 95% CI |
| Al-Kaff y Al Hamad 2024 | 17.8 | 3.7 | 20 | 16 | 2.6 | 20 | 10.5% | 0.55 [-0.08 , 1.18] |
| Badr et al. 2024 | 3.2 | 2.8 | 10 | 4 | 1.8 | 10 | 9.9% | -0.33 [-1.21 , 0.56] |
| Deng et al. 2023 | 8.4 | 1.3 | 10 | 7.4 | 1.2 | 10 | 9.8% | 0.77 [-0.15 , 1.68] |
| Gintaute et al. 2023 | 90.35 | 11.34 | 10 | 91.4 | 9.1 | 10 | 9.9% | -0.10 [-0.97 , 0.78] |
| Inokoshi et al. 2012 | 89.3 | 18.9 | 10 | 89.9 | 18.9 | 10 | 9.9% | -0.03 [-0.91 , 0.85] |
| Iwaki et al. 2024 | 19.6 | 15 | 9 | 17.7 | 12.8 | 9 | 9.8% | 0.13 [-0.80 , 1.05] |
| Kunavisarut et al. 2022 | 9.05 | 0.41 | 10 | 9.5 | 0.69 | 10 | 9.8% | -0.76 [-1.67 , 0.16] |
| Magano et al. 2018 | 93.5 | 3.3 | 25 | 83.6 | 4 | 25 | 10.2% | 2.66 [1.88 , 3.43] |
| Nabil et al. 2024 | 64 | 7.5 | 16 | 62.5 | 8.1 | 16 | 10.3% | 0.19 [-0.51 , 0.88] |
| Ohara et al. 2022 | 61.1 | 5.75 | 20 | 78.83 | 6.41 | 20 | 9.8% | -2.85 [-3.76 , -1.95] |
| **Total (HKSJ[a])** | | | **140** | | | **140** | **100.0%** | **0.03 [-0.94 , 1.01]** |

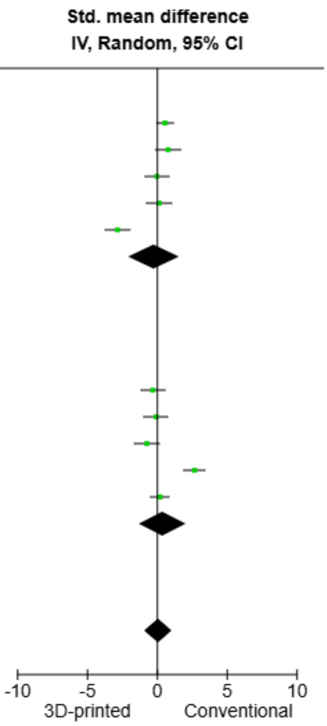



Test for overall effect: Z = 0.08 (P = 0.94)
Test for subgroup differences: Not applicable
Heterogeneity: Tau² (DL[b]) = 1.61; Chi² = 91.19, df = 9 (P < 0.00001); I² = 90%

**Footnotes**
[a]CI calculated by Hartung-Knapp-Sidik-Jonkman method.
[b]Tau² calculated by DerSimonian and Laird method.

**Figure 4.** Meta-analysis of patient satisfaction with 3D-printed versus conventionally fabricated dental prostheses.

| | 3D-printed | | | Conventional | | | | Std. mean difference |
|---|---|---|---|---|---|---|---|---|
| Study or Subgroup | Mean | SD | Total | Mean | SD | Total | Weight | IV, Random, 95% CI |
| **1.1.1 Complete prosthesis** | | | | | | | | |
| Al-Kaff y Al Hamad 2024 | 17.8 | 3.7 | 20 | 16 | 2.6 | 20 | 10.5% | 0.55 [-0.08 , 1.18] |
| Deng et al. 2023 | 8.4 | 1.3 | 10 | 7.4 | 1.2 | 10 | 9.8% | 0.77 [-0.15 , 1.68] |
| Inokoshi et al. 2012 | 89.3 | 18.9 | 10 | 89.9 | 18.9 | 10 | 9.9% | -0.03 [-0.91 , 0.85] |
| Iwaki et al. 2024 | 19.6 | 15 | 9 | 17.7 | 12.8 | 9 | 9.8% | 0.13 [-0.80 , 1.05] |
| Ohara et al. 2022 | 61.1 | 5.75 | 20 | 78.83 | 6.41 | 20 | 9.8% | -2.85 [-3.76 , -1.95] |
| **Subtotal (HKSJ[a])** | | | **69** | | | **69** | **49.9%** | **-0.28 [-2.10 , 1.54]** |
| Test for overall effect: Z = 0.44 (P = 0.66) | | | | | | | | |
| Heterogeneity: Tau² (DL[b]) = 1.79; Chi² = 43.32, df = 4 (P < 0.00001); I² = 91% | | | | | | | | |
| **1.1.2 Implant-supported prosthesis** | | | | | | | | |
| Badr et al. 2024 | 3.2 | 2.8 | 10 | 4 | 1.8 | 10 | 9.9% | -0.33 [-1.21 , 0.56] |
| Gintaute et al. 2023 | 90.35 | 11.34 | 10 | 91.4 | 9.1 | 10 | 9.9% | -0.10 [-0.97 , 0.78] |
| Kunavisarut et al. 2022 | 9.05 | 0.41 | 10 | 9.5 | 0.69 | 10 | 9.8% | -0.76 [-1.67 , 0.16] |
| Magano et al. 2018 | 93.5 | 3.3 | 25 | 83.6 | 4 | 25 | 10.2% | 2.66 [1.88 , 3.43] |
| Nabil et al. 2024 | 64 | 7.5 | 16 | 62.5 | 8.1 | 16 | 10.3% | 0.19 [-0.51 , 0.88] |
| **Subtotal (HKSJ[a])** | | | **71** | | | **71** | **50.1%** | **0.34 [-1.33 , 2.02]** |
| Test for overall effect: Z = 0.56 (P = 0.57) | | | | | | | | |
| Heterogeneity: Tau² (DL[b]) = 1.70; Chi² = 42.82, df = 4 (P < 0.00001); I² = 91% | | | | | | | | |
| **Total (HKSJ[a])** | | | **140** | | | **140** | **100.0%** | **0.03 [-0.94 , 1.01]** |




Test for overall effect: Z = 0.08 (P = 0.94)
Test for subgroup differences: Chi² = 0.50, df = 1 (P = 0.48), I² = 0%
Heterogeneity: Tau² (DL[b]) = 1.61; Chi² = 91.19, df = 9 (P < 0.00001); I² = 90%

**Footnotes**
[a]CI calculated by Hartung-Knapp-Sidik-Jonkman method.
[b]Tau² calculated by DerSimonian and Laird method.

**Figure 5.** Meta-analysis of patient satisfaction with 3D-printed versus conventionally fabricated dental prostheses.

| Outcomes | Anticipated absolute effects* (95% CI) | | Relative effect (95% CI) | № of participants (studies) | Certainty of the evidence (GRADE) | Comments |
|---|---|---|---|---|---|---|
| | Risk with Conventional | Risk with 3D-printed | | | | |
| Patient satisfaction | - | SMD **0.03 SD higher** (0.94 lower to 1.01 higher) | - | 280 (10 RCTs) | ⊕⊕◯◯ Low[a,b,c] | |

**CI:** confidence interval; **SMD:** standardised mean difference, **Low certainty:** our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect; [a] There is variability in the results across studies, possibly due to differences in study design, population characteristics, or outcome assessment methods; [b] Some studies may not be fully applicable to the target population or the exact intervention of interest; [c] Some studies have small sample sizes or wide confidence intervals, which reduces the certainty of the observed effects.

**Table 2.** Summary of findings, certainty of the evidence GRADE.

Rather, the available evidence indicates that no clear superiority of either fabrication method could be established. Satisfaction appears to be influenced not only by the manufacturing workflow but also by prosthesis fit, retention, stability, esthetics, phonetics, masticatory function, material properties, previous expectations, and adaptation over time.

The pooled findings are consistent with several trials reporting comparable overall satisfaction between digitally or additively manufactured prostheses and their conventionally fabricated counterparts. Kang et al. found no significant difference in general satisfaction with complete dentures, although conventional dentures achieved better masticatory efficiency and pronunciation [9]. Nabil et al. similarly reported comparable overall satisfaction and masticatory performance between 3D-printed and conventional implant overdentures, while conventional prostheses received higher esthetic scores [10]. Iwaki et al. observed no significant differences in satisfaction or oral health-related quality of life [11], whereas Ohara et al. identified greater satisfaction with conventional dentures in specific domains, including stability, comfort, pronunciation, and ease of cleaning [12]. Comparable variability has also been observed in implant-assisted mandibular overdentures fabricated from different materials and through different workflows [33], as well as in clinical comparisons between 3D-printed and conventionally fabricated implant overdentures [34]. Evidence from 3D-printed implant-supported fixed prostheses and patient-specific prosthodontic rehabilitation further suggests that favorable patient perceptions may depend on the interaction between prosthetic design, fit, support, material behavior, and clinical execution rather than on the fabrication method alone [35, 36].

The substantial heterogeneity observed in the overall analysis may be explained by differences in study populations, prosthesis types, measurement instruments, and follow-up periods. Satisfaction is a multidimensional and context-dependent outcome, and its evaluation may vary according to the domains included in each questionnaire or rating scale [37]. The included studies assessed temporary crowns, fixed prostheses, complete dentures, bars, and implant overdentures, which differ considerably in biomechanical behavior, support, retention, esthetic demands, and patient expectations. Material-related characteristics may also contribute to variability. Conventional and 3D-printed denture polymers can differ in physicochemical properties and surface behavior [38], while translucency and opacity may influence the esthetic perception of restorative materials [39]. In addition, marginal adaptation, internal fit, fracture resistance, and failure behavior are affected by preparation design, restorative material, manufacturing technique, and aging conditions [40 -42]. Clinical outcomes may also differ between additive and subtractive workflows, reinforcing the need to avoid treating all digital fabrication methods as equivalent [43]. These factors provide plausible explanations for why similar overall satisfaction scores may coexist with differences in specific domains such as esthetics, comfort, stability, or function.

The subgroup analyses did not identify statistically significant differences between fabrication methods for complete dentures or implant-supported prostheses. For complete dentures, the pooled effect was SMD = −0.28 (95% CI: −2.10 to 1.54; $p = 0.66$), whereas implant-supported prostheses showed an SMD of 0.34 (95% CI: −1.33 to 2.02; $p = 0.57$). The test for subgroup differences was also non-significant ($p = 0.48$), although heterogeneity within both subgroups remained high. Clinically, these findings suggest that 3D-printed prostheses may be considered an alternative when indication, material selection, fit, occlusion, post-processing, and quality control are adequately managed. Digital planning and 3D-printing technologies have expanded beyond conventional prosthodontics into complex maxillofacial rehabilitation, demonstrating the broader applicability of digitally guided workflows [44]. Automated CAD design may improve the reproducibility of occlusal morphology [45], while digital workflows can enhance the precision of implant placement and prosthesis fabrication [46]. Nevertheless, masticatory performance and patient experience may be more strongly affected by prosthetic support and retention, particularly in implant overdenture therapy [47]. Economic considerations are also relevant because cost-effectiveness may vary according to prosthesis type, manufacturing infrastructure, maintenance requirements, and treatment setting [48, 49]. Therefore, selection of the fabrication method should be individualized and should integrate patient preferences with clinical, technical, and economic factors.

This review has several strengths, including prospective registration in PROSPERO, compliance with PRISMA 2020, searches across four major databases, independent study selection and data extraction, assessment of risk of bias using RoB 2, evaluation of certainty using GRADE, and the use of random-effects and subgroup analyses. However, important limitations should be acknowledged. The high statistical heterogeneity reduced the precision and interpretability of the pooled estimates. Sample sizes in the primary studies were generally small, follow-up periods ranged from 48 hours to 2 years, and the evaluated prostheses and satisfaction instruments were heterogeneous. Some studies assessed complete additive manufacturing, whereas others evaluated broader CAD/CAM workflows that may have included subtractive procedures.

This variability limits the extent to which the pooled result can be attributed specifically to 3D printing. Furthermore, blinding was often difficult because patients and clinicians could identify differences in prosthetic workflows, which may have influenced a subjective outcome such as satisfaction. Incomplete reporting of allocation concealment, outcome assessment, and selective reporting also contributed to uncertainty and to the low certainty of the evidence.

Future research should prioritize adequately powered randomized clinical trials using standardized and validated multidimensional instruments for patient satisfaction. Overall satisfaction should be reported separately from specific domains, including comfort, retention, stability, esthetics, phonetics, mastication, ease of cleaning, treatment time, and willingness to continue using the prosthesis. Studies should clearly distinguish additive manufacturing from subtractive CAD/CAM procedures and report the printing technology, material composition, build orientation, layer thickness, post-curing protocol, finishing procedures, occlusal adjustments, and maintenance requirements. Standardized short-, medium-, and long-term follow-up intervals are also needed to determine whether patient perceptions change during adaptation and continued use. Further evaluations of complications, prosthesis longevity, number of clinical visits, cost-effectiveness, and patient preferences would help identify the clinical scenarios in which 3D printing provides meaningful advantages over conventional fabrication.

## Conclusions

Current evidence did not demonstrate a statistically significant difference in patient satisfaction between 3D-printed and conventionally fabricated dental prostheses. Likewise, no significant differences were identified in the subgroup analyses of complete dentures and implant-supported prostheses. However, the high heterogeneity among studies and the low certainty of the evidence prevent firm conclusions regarding equivalence or superiority. Therefore, 3D-printed prostheses may be considered a clinically acceptable alternative, but treatment selection should also account for prosthesis type, fit, function, material characteristics, clinical workflow, and individual patient needs.

## Author Contributions Statement (CrediT)

**KAG:** Conceptualization, Methodology, Writing – Original Draft, Supervision. **EEF:** Formal analysis, Data curation, Validation, Visualization. **AJG:** Resources, Project administration, Funding acquisition, Writing – Review & Editing.

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## Conflict of Interest

The authors declare that they have no financial, institutional, professional, or personal relationships that could have affected the design, conduct, analysis, interpretation, or reporting of this systematic review and meta-analysis.

## Data Availability

All data analyzed in this systematic review and meta-analysis were obtained from the published studies included in the review. The data extraction forms and analytical dataset supporting the reported findings are available from the corresponding author upon reasonable request.

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