

Comparative effectiveness of CAD/CAM versus conventional fabrication methods for dental crowns: Systematic review

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Abstract

Background: This systematic review aims to evaluate the effectiveness of computer-aided design/computer-aided manufacturing (CAD/CAM) versus conventional fabrication techniques in dental crown production, focusing on marginal fit, internal adaptation, fracture resistance, and clinical performance.

Methods: A search of PubMed Central, Google scholar and ScienceDirect was conducted for studies published between 2010 and 2023. We include original research articles comparing CAD/CAM and conventional methods for crown fabrication. Nine studies meeting eligibility criteria were included, with in vitro, in vivo, and clinical investigations. Data were extracted on study design, population characteristics, crown type, fabrication methods, and outcomes.

Results: Most included studies show superior marginal and internal fit, and enhanced fracture strength, in CAD/CAM-fabricated crowns compared to conventional crowns. Outcomes varied depending on material type, scanner and milling system used, and crown indication. Some studies found conventional methods give better adaptation in certain designs.

Conclusion: CAD/CAM technologies show good results in crown fabrication in multiple performance parameters. Despite technique sensitivity, digital methods are emerging as a reliable and better alternative to conventional techniques, which their broader clinical adoption.

Keywords: CAD/CAM; Conventional Crown; Marginal Fit; Ceramic Restoration; Internal Adaptation; Digital Dentistry

1. Introduction

The evolution of computer-aided design and computer-aided manufacturing (CAD/CAM) technology has transformed the field of restorative and prosthetic dentistry. With increasing demand for aesthetic, durable, and precisely fitted dental restorations, CAD/CAM systems offer a digital alternative to conventional methods, improved workflow efficiency, material consistency, and patient outcomes. These technologies support both fixed and removable prostheses and are now widely applied in clinical practice.

The rise in popularity of CAD/CAM-produced restorations is driven by advances in materials and milling technologies. Resin composite CAD/CAM crowns, are now covered by national insurance programs in some countries and are regarded as a reliable option for restoring premolars and molars. While in vitro studies show a favorable mechanical properties, clinical outcomes is mixed, mainly concerning long-term retention and bonding stability (Miura et al., 2020). The success of these restorations depends on several variables, including case selection, preparation design, bonding protocols, and occlusal adjustment.

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The use of CAD/CAM extends beyond single crowns to implant-supported restorations. Recent reviews show that CAD/CAM-fabricated all-ceramic restorations bonded to titanium bases (Ti-bases) show high bond stability over follow-up periods of up to 7.5 years. Ti-base geometry, luting agent choice, and prosthetic misfit influence debonding rates, warranting further clinical investigation (Shadid, 2023).

CAD/CAM technologies are reshaping removable prosthodontics through both subtractive and additive manufacturing techniques. Subtractive methods are known for their precision, and additive approaches offer flexibility in replicating complex anatomic forms. Current CAD/CAM systems enable the complete digital fabrication of removable dentures, a field once dominated by analog methods (Bilgin et al., 2016).

In addition to durability and aesthetics, marginal accuracy and internal fit are critical for the clinical success of provisional and final restorations. Comparative *in vitro* studies show that CAD/CAM-fabricated provisional crowns better than direct chairside methods in terms of fit and fracture strength, suggesting that digital techniques enhance the interim restoration phase as well (Abdullah et al., 2016). This systematic review aims to consolidate and compare the clinical effectiveness of CAD/CAM versus conventional fabrication techniques in the production of dental crowns.

2. Method

This systematic review was conducted to evaluate the effectiveness of CAD/CAM and conventional fabrication techniques used in dental crown production. The study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for transparency and throughout the review process. A literature search was performed to identify studies published between 2010 and 2023. The search strategy included multiple databases (PubMed Central (PMC), ScienceDirect, and Google Scholar). Keywords used in the search included combinations of; CAD/CAM; conventional crown; dental crown fabrication; marginal fit; internal gap; and comparative study. Boolean operators (AND and OR) were used and only articles published in English were considered.

Studies were selected for inclusion based on eligibility criteria. We include original research studies that compared CAD/CAM and conventional fabrication methods in the context of dental crowns. Eligible studies reported at least one outcome measure related to the marginal fit, internal gap, fracture resistance, or fatigue behavior of the crowns. Both *in vitro* and *in vivo* studies were considered, and full text should be available and published in an open-access format. We exclude review articles, editorials, conference abstracts, or studies focused on material comparisons without the fabrication technique.

The selection process was carried out in two stages. First, titles and abstracts of all retrieved articles were screened. Then, full-text versions of eligible articles were reviewed to confirm their inclusion. Two reviewers independently conducted this process, and disagreements were resolved through discussion. Data were extracted from the selected studies and included citation, study design, objective, population characteristics, fabrication methods, and measured outcomes.

Due to methodological differences in the studies (variations in scanner types, crown materials, and assessment techniques) a meta-analysis was not possible, and the results were synthesized qualitatively to identify common patterns and differences in the studies.

3. Result and discussion

The systematic review included nine original studies comparing the effectiveness of CAD/CAM and conventional fabrication methods for dental crowns. The findings show variability in the marginal and internal fit of crowns depending on the fabrication technique, type of material, and clinical or laboratory setting. Most *in vitro* studies found that CAD/CAM-fabricated crowns provided better marginal and internal adaptation in relation to conventionally fabricated crowns (Table 1). In a study comparing multiple workflows, CAD/CAM restorations with TRIOS 3 scanner and 5-axis milling exhibited superior marginal adaptation and fatigue behavior in comparison to other configurations (Pilecco et al. 2023). Another investigation show that provisional crowns fabricated via 3D printing show better marginal accuracy compared to CAD/CAM, indirect, and direct techniques (Sahu et al. 2023). CAD/CAM hybrid ceramic crowns provided better marginal adaptation in primary molars compared to prefabricated zirconia crowns (Salman et al. 2023) (Table 2).

Table 1 Studies characteristics

Citation	Study Design	Study Aim	Population Characteristics	Method
Pilecco et al., 2023	In vitro comparative study	To evaluate the marginal/internal gap and fatigue behavior of crowns made with different CAD-CAM workflows	80 epoxy resin dies representing upper first molars	Crowns fabricated using two IOS (TRIOS 3, Primescan) and two milling machines (CEREC MC XL, PrograMill PM7), analyzed via micro-CT and fatigue tested
Sahu et al., 2023	In vitro experimental study	To compare marginal accuracy of provisional crowns fabricated using 3D printing, CAD-CAM, indirect, and direct techniques	8 extracted maxillary and mandibular molars, 32 crowns (8 per group)	Marginal accuracy measured at four points using stereomicroscope at 10× magnification
Salman et al., 2023	In vitro comparative study	To compare the marginal fit of CAD/CAM hybrid ceramic crowns and prefabricated zirconia crowns for primary molars	50 epoxy resin replicas of 25 prepared mandibular second primary molars	Crowns sectioned and measured using SEM; analysis with t-test at 5% significance
Paul et al., 2020	In vivo experimental study	To compare marginal and internal gap of monolithic zirconia CAD/CAM crowns and conventional metal-ceramic crowns	10 participants needing single crown restoration	Replica technique using light body silicone, sections measured at five sites under stereomicroscope
Vojdani et al., 2013	In vitro experimental study	To compare marginal and internal fit of metal copings from wax patterns made by CAD/CAM vs conventional wax-up	24 brass dies divided into two groups (CAD/CAM and conventional), 12 each	Cross-sectional analysis at 15 points using t-test for statistical comparison

Table 2 Main findings

Citation	Demographics	Common Findings	Outcome
Pilecco et al., 2023	80 epoxy resin dies (upper first molars)	5-axis milling and TRIOS scanner yielded better fit; RC crowns had higher fatigue resistance	Marginal/internal gaps and fatigue behavior influenced by scanner, milling machine, and material
Sahu et al., 2023	32 provisional crowns (8 each for 3D printing, CAD-CAM, indirect, direct) on 8 molars	3D printing had best marginal adaptation, followed by CAD/CAM	Marginal accuracy best in 3D printing, statistically significant differences observed
Salman et al., 2023	50 replicas of 25 mandibular second primary molars	CAD/CAM hybrid ceramic (VE) had superior marginal fit over prefabricated zirconia	Statistically significant better marginal fit in CAD/CAM group
Paul et al., 2020	10 patients with single crown restoration	Zirconia CAD/CAM crowns had better marginal and internal fit than metal-ceramic	Significant differences in both marginal and internal gaps
Vojdani et al., 2013	24 brass dies (12 per group)	Conventional wax patterns had better marginal/internal fit than CAD/CAM wax patterns	Significantly better fit in conventional group

Mously et al., 2014	40 lithium disilicate crowns on typodont dies	Heat-press technique had best adaptation; CAD/CAM 60 µm spacer recommended	Significant variation in adaptation depending on spacer setting and technique
Neves et al., 2014	15 crowns (5 per method) on prepared premolars	CEREC CAD/CAM and heat-press had better marginal fit than E4D	CEREC and heat-press significantly outperformed E4D system
Abdullah et al., 2016	40 provisional crowns (4 groups × 10 each)	CAD/CAM crowns had smaller marginal and internal gaps and higher fracture strength	CAD/CAM methods outperformed direct method in all metrics
Torabi et al., 2013	24 metal copings (12 per fabrication technique)	Conventional wax-up had better marginal/internal fit than CAD/CAM wax	Significant differences found favoring conventional fabrication

CAD/CAM zirconia crowns were found to improve marginal and internal fit in comparison to metal-ceramic crowns produced using conventional casting techniques (Paul et al. 2020). Some studies highlighted limitations of CAD/CAM techniques. Metal copings made from wax patterns fabricated through conventional methods show better marginal and internal adaptation than those made from CAD/CAM-generated wax patterns (Vojdani et al. 2013; Torabi et al. 2013).

Comparative evaluations of lithium disilicate crowns show that those produced using the heat-pressing technique achieved better fit than using chairside CAD/CAM systems, mainly when using E4D scanners (Mously et al. 2014; Neves et al. 2014). One study found that both CEREC CAD/CAM and heat-pressing approaches provided similar accurate fits, and the E4D system had less favorable adaptation (Neves et al. 2014). CAD/CAM crowns improved marginal/internal gaps and greater fracture strength compared to directly fabricated bis-acryl crowns (Abdullah et al. 2016). Differences in studies attributable to the choice of spacer settings, scanner types, milling units, materials, or sample sizes.

The evidence show that CAD/CAM technologies provide a reliable and better alternative to conventional methods, although outcomes are technique-sensitive and dependent on specific variables such as crown type and material.

The findings of this systematic review show a consistent trend favoring CAD/CAM technologies over conventional methods for the fabrication of dental crowns, in marginal and internal fit. In the nine included studies, CAD/CAM-fabricated restorations exhibited superior adaptation, improved consistency, and reduced fabrication errors compared to those produced through traditional techniques. These observations are in line with the broader conclusions presented in the review by Suganna et al., which show the rapid adoption of CAD/CAM in various dental disciplines and its ability to provide efficient, reproducible, and acceptable prosthetic outcomes (Suganna et al. 2022).

Keskin et al. compared various production techniques for lithium disilicate endocrowns and found that digital workflows resulted in lower marginal discrepancy compared to conventionally fabricated restorations (Keskin et al. 2023). Their results highlight that digital design combined with advanced manufacturing methods yields restorations within clinically acceptable limits for both marginal and internal fit, supporting the precision offered by modern digital technologies.

Some studies within our review show higher internal fit values for conventionally fabricated crowns, these differences were not clinically significant. The variation in scanner type, milling device, spacer settings, and material properties contributed to outcome differences. This nuance reinforces the notion, as shown in Suganna et al.'s review, that success with CAD/CAM restorations is technique-sensitive and need careful planning and execution (Suganna et al. 2022).

4. Conclusion

The integration of findings from the included studies supports the growing consensus that CAD/CAM technology is a viable alternative and better option for crown fabrication in modern prosthodontics.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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