



Review Article

Current status and perspective of CAD/CAM-produced resin composite crowns: a review of clinical effectiveness

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ABSTRACT

The purpose of the present review was to survey the available literature on computer-aided design/computer-aided manufacturing (CAD/CAM)-produced resin composite materials to provide clinicians with a current overview of the key components necessary for daily clinical use. An electronic search was conducted in the PubMed database. Peer-reviewed articles in English language on the use of resin composites in CAD/CAM dental crowns were included. A total of 122 full-text articles were identified, 15 of which were selected during the initial review. Two additional articles were also discovered through a manual search, to obtain a final total of 17 articles included in the present review. Of these, 16 were to *in vitro* studies, and one was an *in vivo* study. Findings from the *in vitro* studies indicate that resin composite block materials for CAD/CAM applications demonstrate excellent physical properties and are appropriate for the clinical restoration of premolars and molars. However, the *in vivo* study reported a low 3-year success rate, but high survival rate for resin composite CAD/CAM crowns placed in the premolar region. The key to ensuring the successful prognosis of a resin composite CAD/CAM crown is to ensure that all steps—such as proper case selection, abutment tooth preparation, occlusal adjustment, and bonding—are accurately performed.

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1. Introduction

In Japan, growth in the number of computer-aided designed/computer-aided manufactured (CAD/CAM) crowns produced from resin composite blocks continues, due to increased coverage by National Health Insurance since 2014. Against this backdrop, advances in dental materials, CAD/CAM, and adhesive technologies, as well as financial considerations, have contributed to this gain in popularity.

The resin composite block materials used for dental CAD/CAM applications are manufactured by compressing and polymerizing a filler and a monomer. The mechanical properties, such as flexural strength, of the newer resin composite blocks, have been improved in comparison to the conventional resin composite polymerized blocks. Fillers used in blocks include silica, alumina, and zirconia. The choice of filler varies between manufacturers, as does the particle size of the filler. According to the definition by the Ministry of Health, Labor and Welfare, for premolars, the total weight separa-

tion of silica fine powder and the inorganic filler excluding it is 60% or more; for molars, the total weight separation of silica fine powder and the inorganic filler excluding it is 70% or more. Both resin blocks are produced by heat and chemical polymerization, the latter using peroxide as a catalyst. These CAD/CAM resin composite materials supposedly combine the positive physical, mechanical, and esthetic properties of ceramics and composites. It is reported that the dual network of ceramic and polymer reduces brittleness and provides excellent machinability and edge stability [1].

When the CAD/CAM resin composite crown was introduced as an approved treatment procedure covered by National Health Insurance in Japan, use was restricted to the restoration of premolars alone (Fig. 1). Currently, however, indications for use have expanded to include the first molars (Fig. 2). Clinical studies on CAD/CAM crowns have been conducted before they were covered by the National Health Insurance, and some clinical prognoses in Japanese literature have been reported (Table 1). Hikita et al. assessed 51 CAD/CAM crowns fitted on premolar teeth over a duration of 9.4 months. Apart from some loss of gloss and slight discoloration, no other problems, in terms of the effectiveness of resin composite as a crown material, were identified (Table 1-J1). In addition, several 2- to 3-year clinical evaluations of premolar

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Table 1
Clinical studies of CAD/CAM resin composite crown reported in the Japanese literature.

Code	Author	Paper type	Tooth type	Outline	Journal
J1	Hikita K et al.	Original	Premolar	Examination of the prognosis of 51 crowns for 9.4 months showed some loss of gloss and coloration, however no other problems, demonstrating their effectiveness as a crown material.	Ann Jpn Prosthodont Soc, 1: 64–70, 2009
J2	Suese K	Original	Premolar	Investigation research on the initial follow-up of CAD/CAM crowns introduced to insurance medical treatment.	Journal of the Japan Academy of Digital Dentistry, 5: 85–94, 2015
J3	Shinya A et al.	Review	Premolar	The risk factors of CAD/CAM crown troubles were clarified, and in order to be able to cope with them, the abutment tooth preparation form, resin composite block characteristics, appropriate bonding procedure, and postoperative management were discussed.	Ann Jpn Prosthodont Soc, 9: 1–15, 2017
J4	Yamase K et al.	Original	Premolar	The CAD/CAM crowns were cases of loss of retention of the crown and fracture, suggesting that attention should be paid to the selection of indications and adhesion operation.	Ann Jpn Prosthodont Soc, 9: 137–144, 2017
J5	Yoshida K et al.	Original	Anterior	No cracks, fractures or loss of retention of the crowns were found in any incisor CAD/CAM crown. In each one case, slight roughness and loss of gloss, and discoloration and coloring were observed.	Journal of the Japan Academy of Digital Dentistry, 8: 112–119, 2018
J6	Hikita K et al.	Original	Molar	Examination of the prognosis of 21 crowns for 8.5 months showed no problems in all cases, suggesting that it is effective as a material for molar crowns.	Journal of the Japan Academy of Digital Dentistry, 8: 120–124, 2018
J7	Suese K et al.	Original	Premolar	Expanding the application to molars and anterior teeth, material strength and color reproducibility will be improved, and consideration for loss of retention of the crown and fracture will be extremely is important.	Ann Jpn Prosthodont Soc, 11: 45–55, 2019
J8	Igarashi K et al.	Original	Premolar	The complication of the CAD/CAM crown was frequently loss of retention. It is important to control the technique-sensitive factors by understanding the selection of the abutment tooth, dental materials, and the bonding system.	Ann Jpn Prosthodont Soc, 11: 383–390, 2019



Fig. 1. Clinical photograph of a resin composite CAD/CAM crown for the restoration of a premolar tooth; initially covered by National Health Insurance in 2014.



Fig. 2. Clinical photograph of a resin composite CAD/CAM crown for the restoration of a maxillary first molar; expanded indication for use covered by National Health Insurance from 2020.

CAD/CAM crowns have been documented; all reported a loss of crown retention as the main complication (Table 1-J2, -J3, -J4, -J7, -J8). These researchers isolated no single causative factor for this loss, suggesting instead that multiple factors might be involved. With respect to anterior CAD/CAM crowns, no reports of cracks, fractures, or retention loss were found (Table 1-J5). Furthermore,

molar CAD/CAM crowns demonstrated no retention loss, and no fractures in any cases (Table 1-J6). These Japanese studies revealed that loss of retention occurred more frequently in CAD/CAM crowns

Table 2
Search details of PubMed database.

Search strategy	Items found
((CAD/CAM[All Fields] AND (composite resins[MeSH Terms] OR (composite[All Fields] AND resins[All Fields]) OR composite resins[All Fields] OR (composite[All Fields] AND resin[All Fields]) OR composite resin[All Fields])) AND (crowns[MeSH Terms] OR crowns[All Fields] OR crown[All Fields])) NOT (dental bonding[MeSH Terms] OR (dental[All Fields] AND bonding[All Fields]) OR dental bonding[All Fields])	122

than in conventional crowns. The causes underlying this retention loss remain unknown, and no definitive conclusions have been reached. Moreover, the anterior and molar CAD/CAM crowns were evaluated shortly after insurance coverage came into effect; therefore, the true/actual prognosis has not been clarified.

The optimal clinical procedure to obtain an ideal long-term prognosis for CAD/CAM crowns has not yet been elucidated. Therefore, the purpose of the present review was to survey the available literature on resin composite CAD/CAM crowns to provide clinicians with a current overview of the requirements for successful daily clinical use. Since the review article by Mine et al. [2] on dental bonding is detailed, the description of dental bonding is omitted in this paper.

2. Materials and methods

An electronic search was conducted in the PubMed database, using query terms shown in Table 2. This review included studies that focused on the clinical effectiveness of CAD/CAM-produced resin composite crowns. Peer-reviewed articles in English language on the use of resin composites in the CAD/CAM of dental crowns were included. Conversely, studies that incorporated dental bonding tests, case reports, or papers that focused predominantly on ceramics, implants, onlay/inlays, endocrowns, or interim restorations were excluded. Following the initial search, the titles and abstracts of all articles were carefully appraised for possible inclusion in the review. Thereafter, the full-text of each eligible article was critically reviewed. To supplement the database search, a manual search for suitable articles was conducted.

3. Results

A total of 122 full-text articles were identified, 107 of which were excluded during the initial review. Two additional articles discovered through a manual search were also included, to obtain a final total of 17 articles included in the present review (Fig. 3, Table 3). The papers that were assessed were published between September 1, 1996, and April 30, 2020. However, those finally selected for inclusion were all published after 2015, highlighting the increased interest that this research field has garnered in recent years. Of the 17 selected articles, 16 pertained to *in vitro* studies, and one an *in vivo* study.

3.1. In vitro studies

The major focus of these articles was the fracture strength of the CAD/CAM resin composite materials [3–9]. A majority concluded that the current, commercially available CAD/CAM resin composite blocks have sufficient strength to be suitable for use on molar teeth [4–6]. Fracture strength testing revealed that resin composite CAD/CAM crowns chipped minimally and were repairable (Cerasmart, GC, Japan). A polymer-infiltrated ceramic network material did not de-bond readily, with less than half demonstrating a loss of retention (Vita Enamic, VITA, Germany), whereas the glass-ceramic CAD/CAM crowns were found to be more prone to catastrophic

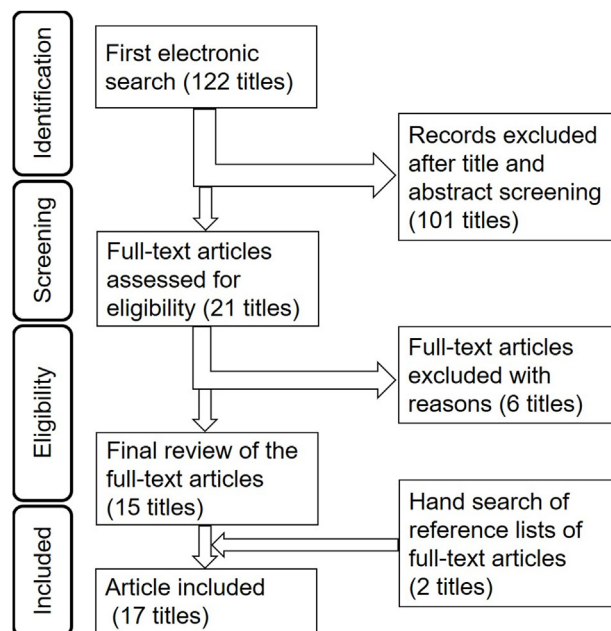


Fig. 3. Search strategy and included studies.

and irreparable fracture [7]. Furthermore, it has been reported that CAD/CAM resin composite materials exhibit a fracture strength three to four times greater than the average, maximum occlusal force generated by a molar tooth (700–900 N) [4,6]. A study that examined the effect of differences in the axial thickness (four types with radius of curvature of 0.15, 0.30, 0.45, and 0.60 mm) of CAD/CAM crowns and bonding agents (composite resin cement, MMA resin cement, or polycarboxylate cement) used found that the fracture loads of the crowns were not influenced by differences in the axial thickness. However, the fracture load value attained was higher for resin cement-bonded as opposed polycarboxylate cement-bonded crowns [8]. Rosentritt et al. reported that water storage (no vs. 90 d/37°C) affected retention, while the type of cement used (adhesive vs. self-adhesive) marginally influenced performance and fracture force [9]. In addition, the mean flexural strength and modulus of resilience of the polymer-based materials (Cerasmart, GC; Lava Ultimate, 3M, USA) were determined to be significantly higher than those calculated for the other CAD/CAM restorative materials (Vita Enamic, VITA; Paradigm MZ100 Block, 3M; Vitablocs Mark II, VITA; IPS Empress CAD, Ivoclar Vivadent, Lichtenstein) [3].

Four articles on material fatigue behaviors were reviewed. Anky et al. reported that resin composite CAD/CAM crowns for molars demonstrate potential for clinical application in terms of fatigue resistance [10]; the resistance of crowns to microscale expansion and contraction caused by thermal and mechanical fatigue play an important role in maintaining retentive strength [11]. Likewise, Yamaguchi et al. argued that resin composite CAD/CAM molar crowns exhibited higher fracture loads and greater longevity than ceramic CAD/CAM molar crowns, suggesting that, in terms of fatigue behavior, these crowns could be used as an alternative to ceramic crowns [12]. Furthermore, it has been reported that resin composite CAD/CAM crowns can endure an exceptionally high fatigue load. Therefore, this material meets the mechanical requirements for high stress-bearing molar crowns, showing excellent resistance to contact and flexural damage [13].

Several articles included in the present literature review reported on microleakage, surface roughness, and wear. First, with respect to the influence of different luting systems, one study found that when resin composite CAD/CAM crowns were subjected to

Table 3
Summary of studies selected for review for CAD/CAM-produced resin composite blocks.

No	Author (year)	Study	CAD/CAM resin composite blocks	Conclusions
#1	Furtado de MA et al. (2019)	Compare the microstructure, flexural strength, flexural modulus, fracture strength, and microhardness of CAD/CAM materials	Cerasmart, Vita Enamic	All CAD/CAM crown materials exhibited high values of fracture and flexural resistance, making them suitable materials for posterior full-crown restorations.
#2	Matsuda T, et al (2019)	Differences in axial thickness and type of cement on fracture resistance	KZR-CAD HR	The fracture load values of CAD/CAM resin composite crowns are not influenced by differences in the axial thickness of the crown, and that they are higher when bonding is achieved with resin rather than polycarboxylate cement.
#3	Miura S et al. (2019)	3-year retrospective clinical study	Lava Ultimate, Cerasmart, Gradia Block, Shofu Block HC, KZR-CAD HR	CAD/CAM resin composite premolar crowns presented a 3-year success rate of 71.7 % and a survival rate of 96.4 %. The most common complication was early loss of retention of the crown, which is a reversible complication.
#4	Okamura K et al. (2019)	Surface properties and gloss of CAD/CAM composites after toothbrush abrasion testing	Cerasmart 300, Estelite P Block, Katana Avencia P block, KZR-CAD HR3 Gammatheta	The gloss of Estelite P block and KZR-CAD HR3 Gammatheta was greatly decreased and surface roughness was greatly increased. Periodic recall and re-polishing may thus be necessary when these products are used clinically.
#5	Rosentritt M et al. (2019)	Compare the debonding and fracture force of different CAD/CAM composite crowns with respect to the influence of water storage and types of cementation.	Cerasmart, Experimental, Lava Ultimate, Vita Enamic	Debonding and stability of CAD/CAM crowns were material dependent. Water storage affected debonding, and cementation marginally influenced performance and fracture force.
#6	Schlenz MA et al. (2019)	Different luting systems on microleakage	Lava Ultimate, LuxaCam Composite	Light curing specimens showed significantly lower microleakage compared to chemical curing specimens.
#7	Tanaka K et al. (2019)	Two-body wear test using bovine enamel	Cerasmart, Estelite Block, Katana Avencia Block, KZR-CAD HR, Lava Ultimate, Shofu Block HC Cerasmart	Resin composite used for CAD/CAM crowns showed greater wear volume in the abraded specimen.
#8	Ankyu S et al. (2018)	Influence of thermal and mechanical cycling on retentive strength of CAD/CAM resin composite crowns.		The resistance of crowns to microscale expansion and contraction caused by thermal and mechanical fatigue would play an important role in maintaining retentive strength.
#9	Mete A et al. (2018)	Compare fracture resistance force (FRF) and failure types of crowns	Lava Ultimate	CAD/CAM crowns milled for the molars promised to be used as an alternative for the full-coronal coverage.
#10	Okada R et al. (2018)	Ascertain whether CAD/CAM resin composite crowns were sufficient strength to withstand the bite force of the molar teeth.	Shofu Block HC, KZR-CAD HR, KZR-CAD HR2, Katana Avencia Block	All CAD/CAM resin composite crowns presented higher fracture strength than the average maximum bite force of the molar teeth.
#11	Yamaguchi S et al. (2018)	Fatigue behavior and crack initiation	Cerasmart, Katana Avencia Block, Shofu Block HC	CAD/CAM resin composite molar crowns containing nano-fillers with a higher fraction of resin matrix demonstrated higher fracture loads and greater longevity
#12	Ankyu S et al. (2016)	Analyze the fatigue behavior of CAD/CAM resin-based composites to simulate 5 year of clinical service.	Lava Ultimate	The flexural strength was not severely reduced by fatigue treatments, the potential of clinical application of CAD/CAM resin composite molar crowns in terms of fatigue resistance.
#13	Shembish FA et al. (2016)	Demonstrate the fatigue behavior of CAD/CAM resin composite molar crowns using a mouth-motion step-stress fatigue test.	Lava Ultimate	This resin composite material meets the mechanical requirements for high stress-bearing posterior restorations, showing excellent resistance to contact and flexural damage.
#14	Awada A et al. (2015)	Determine and compare flexural strength, flexural modulus, modulus of resilience and the margin edge quality of recently introduced polymer-based CAD/CAM materials.	Lava Ultimate, Vita Enamic, Cerasmart	This study exhibited significantly higher flexural strength and modulus of resilience, along with lower flexural modulus values compared with the tested ceramic or hybrid materials. Crowns milled from the resin-based blocks seemed to exhibit visibly smoother margins.

Table 3 (Continued)

No	Author (year)	Study	CAD/CAM resin composite blocks	Conclusions
#15	Harada A et al. (2015)	Fracture resistance of CAD/CAM resin composite molar crowns	Lava Ultimate	CAD/CAM resin composite crowns showed higher fracture load than the bite force reported in previous studies.
#16	Koizumi H et al. (2015)	Surface roughness and gloss of CAD/CAM resin composites before and after toothbrush abrasion	Vita Enamic, Gradia Block, Shofu Block HC, Lava Ultimate, Katana Avencia Block, Cerasmart	A significant difference in the gloss unit was detected the Shofu Block HC. The Ra and Rz of the Cerasmart and Shofu Block HC materials were significantly larger after toothbrush abrasion.
#17	Lauvahutanon S et al. (2015)	Two- and three-body wear of CAD/CAM blocks.	Shofu Block HC, Cerasmart, Gradia Block, Lava Ultimate, Vita Enamic	All CAD/CAM block materials investigated displayed low wear compared to previous data for the same wear test.

masticatory simulations, specimens that were fitted to the abutment using light cure bonding agents demonstrated significantly lower microleakage *versus* those fitted using chemical-cure adhesives [14]. Second, toothbrush abrasion testing revealed a marked decrease in the gloss and increase in the surface roughness of the CAD/CAM resin composite materials relative to that observed for the ceramic materials, highlighting a potential need for maintenance and repolishing of resin composite restorations when used clinically [15,16]. Third, resin composite CAD/CAM crowns showed greater wear and volumetric loss, when opposed by ceramics/enamel [17]. However, Lauvahutanon et al. reported that when subjected to the same wear test, CAD/CAM resin composite block materials displayed lower wear, less weight/volumetric loss, in comparison to previously reported data for direct posterior composites. Hence, the resin composite materials were deemed suitable for fabrication of single, full-coverage crowns on premolar teeth [18]. The authors further concluded that CAD/CAM resin composite block materials have excellent physical properties and may be applied clinically in restoration of both premolar and molar teeth. In addition, as the resin composite block materials are not as hard as the ceramic block materials, wear of the antagonist teeth was reduced.

3.2. In vivo study

Only one *in vivo* study was reviewed—a three-year retrospective study of CAD/CAM crowns. Miura et al. reported that a three-year retrospective cohort study of 547 CAD/CAM crowns for premolars exhibited a success rate of 71.7% and a survival rate of 96.4% [19]. A total of 87 crowns presented with clinical complications; the main complications identified as a retention loss (70 crowns), followed by fracture (9 crowns). In one case, partial fracture (chipping) of the CAD/CAM crown (fabricated with Cerasmart, GC) was observed 1-year post-placement, and the fractured part was polished (Fig. 4). This finding was consistent with the *in vitro* study of Furtado et al. [7]. Furthermore, Miura et al. reported many reversible technical complications, including the loss of crown retention. Thus, despite the low success rate, debonded crowns can be recemented, allowing for improvements in and attainment of a high survival rate. In addition, the authors highlighted a substantial risk of complications with the placement of CAD/CAM crowns on a removable partial denture abutment tooth.

4. Discussion

The present review of 17 articles found that *in vitro* studies relating to strength, fatigue, gross staining, and surface roughness of CAD/CAM resin composite blocks have been undertaken; excellent physical properties applicable to the restoration of premolar and molar teeth with full coverage crowns were reported. Conversely, the only *in vivo* study examined, described a reten-



Fig. 4. Chipping of the distobuccal surface (black arrow) of a CAD/CAM crown (fabricated with Cerasmart, GC, Japan), seated on the right mandibular second premolar. Chipping occurred one year post-cementation. Note the abrasive trace affecting the mesio Buccal surface of the metal crown seated on the first mandibular molar, signifying a concentration of occlusal force in this region (white arrow).

tion loss early post-placement. However, this loss was regarded as a reversible complication, resulting in a low 3-year success rate but high survival rate. Recementing a crown after a loss of retention represents one of the treatment options that is available to reverse this complication. As crowns can lose retention even under a reliable bonding operation, appropriately informing patients pre-operatively is a prerequisite. In general, CAD/CAM crowns debond more frequently than conventional prostheses [20]. Currently, the reason for retention loss has not been clarified. However, it is suspected that multiple factors are at play. Retention loss cannot be explained by the form of the abutment tooth or bonding procedure alone. In the future, it will be necessary to accumulate additional cases and long-term follow-up data, to completely investigate the causes of retention loss.

Since 2014, the Japanese Prosthodontic Society has published guidelines with respect to the use of CAD/CAM crowns [21,22]. According to these guidelines, indications for use include sufficient crown height, absence of excessive occlusal pressure, and sufficient axial wall thickness. Conversely, use is contraindicated for patients that present with significant attrition and/or bruxism, when the interocclusal clearance cannot be guaranteed, or the abutment tooth is undersized. In addition, use should be avoided for a removable partial denture abutment tooth, for a premolar that is the most distal tooth in a quadrant (*i.e.*, the posterior teeth are missing) and in patients with demanding aesthetic expectations. Although the present review uncovered no evidence to support the use of a CAD/CAM crown on a removable partial denture abutment tooth, the *in vivo* study that was included, cited this as a risk factor for complications [19]. From the preceding discussion, it follows

that factors that allow for a successful clinical outcome when using CAD/CAM crowns include sufficient crown height, adequate clearance with antagonist teeth, appropriate retention without the need for auxiliary measures (grooves or holes), and acceptable occlusal pressure or stress.

Cementation of resin composite CAD/CAM crowns is performed using an adhesive resin cement to completely lute the crown to the abutment tooth. Following intraoral try-in, the fitting surface of the CAD/CAM crown should be treated with alumina air abrasion under low pressure. Once the aluminum oxide particles have been removed using air spray a primer containing a silane coupling agent is applied. On drying, the luting agent is applied to the fitting surface of the crown, the crown is seated on the abutment tooth intraorally and irradiated with a curing light for a few seconds to partially cure the adhesive. At this point, the excess cement is removed. Depending on the type of resin cement used, the tooth surface may need to be treated. Mine et al. summarizes the essential steps of the bonding operation as “blasting and priming the inner surface of the crown after trial fitting” and “primer (bonding) to the abutment tooth.” Self-adhesive resin cements are not recommended [2,23,24]. The key to a successful clinical outcome when restoring teeth with resin composite CAD/CAM crowns requires that each step from diagnosis to cementation be performed accurately.

From the clinical report of Miura et al. [19], it is clear that the occurrence of CAD/CAM crown fracture is extremely low in comparison to the loss of crown retention. During abutment preparation, it is not considered necessary to remove more of the abutment tooth than is absolutely required. Inappropriate occlusal adjustment and introduction of excessive fissures during milling, offer the most likely explanations for crown fracture. In addition, an improper try-in and fitting procedure could be linked to crown fracture.

Although the choice of a CAD/CAM system is also important, the physical and mechanical properties of the resin composite block materials are maximized through integration with basic techniques, such as abutment tooth preparation, occlusal adjustment, and cementation.

5. Conclusion

Based on the present comprehensive literature review, the key to the successful prognosis of a resin composite CAD/CAM crown relies not only on the excellent physicomaterial properties of the material and correct application thereof but also on the accurate clinical performance of each procedural step, such as proper case selection, abutment tooth preparation, bonding, and occlusal adjustment.

Conflict of interest

The authors have no conflicts of interest to declare.

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