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A review article: CAD-CAM in removable dental prosthesis

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***Abstract*---**Removable dentures are a treatment option for replacing missing teeth. Use of digital technologies in manufacturing of removable dental prosthesis is a recent innovation with computer-aided (CAD-CAM) design and computer-aided manufacturing. Additive or subtractive methods can be used for the fabrication of removable dentures. This is a review that includes articles from the last 5 years on the use of CAD-CAM for manufacture of removable prostheses. The most frequent failures of the conventional system in the manufacture of removable dental prosthesis should avoid with digital workflow in clinical procedures, fabrication methods and materials used. One of troubles with intraoral scans for removable dentures have been a lack of accuracy and difficulties in capturing soft tissues because. Manufacturing of removable dental prostheses with CAD-CAM has proven properties clinically acceptable, with milled, 3D printer or laser-sintered methods. CAD-CAM-milled and rapid-prototyped of removable denture are similar in terms of biocompatibility and surface roughness. This technology allows exploring the use of new materials such as PEEK for the manufacture of frameworks for removable prostheses, when the use of metallic materials is not possible. In conclusion, digital scanning, three-dimensional printing or milled method is more efficient and more comfortable, allowing advantages in terms of time and cost of prosthesis with predictable results. New studies are needed to show the benefits of CAD-CAM technology in removable dental prosthesis.

***Keywords*---**CAD-CAM, denture, intraoral scans, removable dental prosthesis, three-dimensional printing.

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Introduction

In dentistry is common use computer-aided design (CAD)/computer-aided manufacturing (CAM) for confection of inlays, onlays, veneers, crowns, fixed partial dentures, implant abutments, and full-mouth reconstruction, but is recent for the fabrication of removable dental prostheses (Suganna et al., 2022). Because of the higher costs and need for surgical procedures in implant-supported prostheses, removable dentures continue to be widely provided as a treatment option for replacing missing teeth (Nishiyama et al., 2020).

The conventional 'flask-pack-press' technique for the fabrication of removable complete dentures (RCD) has been gold standard for about more than 50 years. The material from which they are fabricated is polymethyl methacrylate (PMMA) resin, which has improved in properties over time. Unpolymerized PMMA is molded under pressure and then polymerized. This process remained constant until the advent of CAD-CAM (Srinivasan et al., 2018).

The most frequent failures of the conventional system in the manufacture of RCD are material porosity and volumetric shrinkage. Porosity can be internal or external, possibly due to monomer evaporation caused by uncontrolled high temperatures during curing cycles or inhomogeneous mixing and inadequate pressure at the time of manufacture. Volumetric shrinkage is inherent to the polymerization process in the conventional flask-pack-press technique (Srinivasan et al., 2018).

The conventional method of making metal bases for removable partial denture (RPD) is by casting the metal bases with cobalt-chromium or cobalt-nickel alloys (Bridgeport, 1993), being the first used traditionally as the standard framework material due to its desirable mechanical properties and biological stability (Nishiyama et al., 2020). These alloys have mechanical properties, particularly yield strength, rate of work hardening and percentage elongation, acceptable for the clinical requirements (Bridgeport, 1993).

One of the problems with this alloy Cobalt–chromium (Co-Cr), however, is the associated complicated framework fabrication procedure due to a high casting temperature. Over the last decade, digital dentistry based on CAD-CAM has been increasing (Nishiyama et al., 2020). Using digital technologies is rising in manufacturing of removable prosthodontics. This narrative review is about clinical procedures, fabrication methods and materials used on removable dental prostheses using CAD-CAM.

Materials and Methods

This is a narrative review of relevant articles about the use of CAD-CAM in the manufacturing of removable dental prostheses. A PubMed search was conducted for studies published from May 2018 to May 2023 on the clinical procedures, fabrication methods and materials used on removable dental prostheses using CAD-CAM. Reviews, meta-analyses, in vitro studies, clinical case reports and randomized clinical trials were included. Inclusion criteria focused on removable complete and partial dentures and the use of CAD-CAM for its manufacture. The following search strategies were used: (removable denture OR removable dental prosthesis) AND (CAD/CAM OR 3D-printing). With search filters for the last 5 years.

The research strategy for this review included 2 stages: review of abstracts and final selection of articles in English for full-text analysis. The articles selected from the database search were independently classified by 2 reviewers, and differences in the selection were discussed until a consensus was reached.

Results and Discussion

CAD-CAM fabrication of removable dentures was described in the 1990s for the first time, and it has become massively popular in the last few years. This is the result of several critical factors such as: improved materials used to manufacture removable dentures, reduced clinical time in the office, reduced patient visits and lower costs for the clinical laboratory (Guo et al., 2022).

RCDs are often fabricated using the CAD-CAM technique by three-dimensional (3D) printing or milling of prefabricated resin discs. However, fabrication of a RPD using digital technologies is still a work in progress (Piao et al., 2022), and it can be 3D impression or by milling for the framework in metal alloys or other material (Guo et al., 2022). To obtain removable prostheses with digital workflow, several studies reported successful applications of a variety of digital techniques for impression making, jaw registration, arrangement of artificial teeth and designing of denture bases, and manufacturing of the denture base and artificial teeth (Nishiyama et al., 2020).

3D printing is an additive technique that allows for cost reduction, less sophisticated equipment and lower operating costs, and quality removable dentures at a lower cost. However, there are factors that influence the printing result, such as light intensity, number of layers, angle of printing, shrinking, and amount of supporting structures and postprocessing (Maniewicz et al., 2022).

Removable Complete Denture

The use of 3D printing for the fabrication of RCD is the development stage. Commercial companies have been using subtractive CAD-CAM, but more and more people are making complete removable dentures with 3D printing using the additive technique (Srinivasan et al., 2021). The conventional method requires between 5-6 appointments for the fabrication of the RCD. Elderly people, who represent the majority od edentulous patients, may have difficulty attending appointments due to health problems. With digital methods, the number of visits is reduced. Digital intraoral scanning replaces impression taking and reduces costs (Arakawa et al., 2022).

Intraoral scans for removable dentures have been questioned because of a suggested lack of accuracy and difficulties in capturing soft tissues because of the difference in the morphological and histological features of edentulous arches, tissues offer a different resistance to pressure. The 3D difference between the intraoral scan and conventional impression was not statistically significant (−0.02

±0.05 mm) in a clinical study. The size of the measured mean distance can be related to the different physics behind the 2 impression methods and not to the error or defects in accuracy of one method compared with those of the other, because the intraoral scan is a mucostatic impression, whereas every impression material exerts some pressure on the oral mucosa (Lo Russo et al., 2020).

Additive or subtractive methods can be used for the fabrication of removable dentures. Stereolithography (SLA) and digital light processing (DLP) are the two most popular technologies in 3D printing. The use of SLA became the most common because of its excellent resolution and printing speed. DLP is a technology derived from SLA where a flat image of light is projected on a photopolymerized resin, DLP offers lower cost, speed and excellent resolution (Alalawi et al., 2023).

CAD-CAM milling involves a subtractive process on a pre-polymerized PMMA disc in the digitally designed shape. By planning digitally, a wider range of prosthetic designs can be made for different clinical cases (Srinivasan et al., 2018). In the impression of RCD, the denture bases are printed and the prosthetic teeth are separately bonded with PMMA resin. There are impression parameters that determine configuration of the object such as: light intensity, output position, build angle, thickness, and the number of layers (Anadioti et al., 2020; Alalawi et al., 2023).

The accuracy of the impression of the prosthetic teeth will affect the occlusal contacts and contribute to a balanced occlusion, improving the retention of the RCD. When analyzing teeth made by SLA and DLP the in vitro study showed that all were in a clinically acceptable range. The pits and fissures of posterior teeth tend to accumulate resin and should be removed before the curing process (Alalawi et al., 2023).

A study found that the fabrication of RCD in edentulous patients, whether milled or 3D-printed, significantly improves masticatory efficiency, which is achieved when the denture is fully seated in the supporting tissues. The milled prostheses entailed fewer maintenance checks and adjustments, but this was not reflected in higher patient satisfaction compared to the 3D-printed prostheses. The study demonstrated that both treatment modalities are valid for the treatment of edentulous patients (Alalawi et al., 2023).

CAD-CAM-milled and rapid-prototyped RCD are similar in terms of biocompatibility and surface roughness. CAD-CAM-fabricated RCD when compared to 3D-printed ones show better mechanical properties such as flexural strength, flexural modulus, yield strength, toughness, surface properties and color stability (Srinivasan et al., 2021).

A controlled clinical study concluded that the conventional, subtractive and additive methods are suitable for the fabrication of RCD, the patients in the study had positive evaluations for all 3 fabrication methods, and saliva did not affect the retention and fit of the dentures (Maniewicz et al., 2022). Digital dentistry allowed advantages in terms of time and cost of prosthesis with predictable results (Srinivasan et al., 2021; Maniewicz et al., 2022).

Removable Partial Denture

The manufacture of RPD structures is possible: A) By casting a wax structure which is replaced by a metal alloy. B) By subtraction where material is milled from solid blocks. C) By addition: where a structure is made by adding, applying and depositing material. The most used material is metal. The most commonly used additive technologies in RPD are selective laser melting (SLM) sintering and direct metal laser sintering (DMLS), RPDs fabricated with these systems fit very precisely to the supporting tissues of partially edentulous patients (Stamenković et al., 2023).

A study did show the negative effects of the presence of edentulous space on the intraoral scans of partially edentulous dentitions. Qualitative assessments were also visualized, discrepancies were evident majorly in the mid-palatal area, edentulous ridges, and buccal and palatal regions of different teeth. The severe distortions of the mid-palatal area would have detrimental effects on how the maxillary partial removable dental prosthesis framework would fit intraorally. Kennedy Class IV partially edentulous condition showed the best trueness of intraoral scanning and the least amounts of discrepancies in both edentulous spaces (soft tissue) and remaining dentition (hard tissue) regions. On the other hand, Kennedy Class II and Class III modification I displayed the lowest trueness of intraoral scans (Majeed-Saidan et al., 2022).

Variation in scanning may be observed while scanning dental form with flexible soft tissue, when compared to intraoral tissues or the stone dental casts. The presence of clinical factors such as saliva, reflective surfaces of teeth and gingiva, and the movement of patients or soft tissues during scanning can also impact the accuracy of intraoral scans. The small rest seats and other anatomical details on the remaining teeth may also increase the difficulties of intraoral scanning (Majeed-Saidan et al., 2022).

RCD made by CAD-CAM milling and conventional methods had a similar number of adjustments. CAD-CAM prostheses could replace conventional prostheses by reducing costs and clinical treatment time (Arakawa et al., 2022). Digital scanning is more efficient and more comfortable than traditional impressions, and also allows additional RCDs to be fabricated with data stored by the intraoral scanner (Deng et al., 2021). The reproducibility of the PMMA resin milling method together with the improved mechanical properties are making it the new standard in the fabrication of RCD (Maniewicz et al., 2022).

Accuracy of fit of metal frameworks measured the rest and the major connector are the most important parts for accurate fit of the metal framework. The major connector is believed to exhibit the greatest amount of deformation during metal additive manufacturing. Tasaka showed smaller overall differences in the additive frameworks manufacturing with a direct metal laser sintering machine SLS using Co-Cr alloy powder than the cast frameworks using Co-Cr alloy in a high-frequency centrifugal casting machine, suggesting that SLS frameworks are superior in fabrication accuracy and reproducibility (Tasaka et al., 2021).

In a study it was found that cast and laser-sintered Co-Cr, in terms of fatigue resistance and behaviors, showed no significant difference regardless of the manufacturing method. The results showed that all RPD materials, both cast and laser-sintered, had sufficient fatigue resistance for clinical use in the various undercut depths (Zheng, 2022).

Comparing digital study, mixed and analog RPDs, it was found that the ability to view the scanned arches on the computer screen allowed immediate feedback and any errors could be corrected relatively easily. The RPDs that were SLM made of Co-Cr alloy showed a better fit than the cast analog RPDs and also required less time in the office to evaluate the fit (Tregerman et al., 2019).

A study aimed to evaluate the corrosion behavior in artificial saliva with different pH values of two commercial cobalt-chromium dental alloys manufactured by casting and by milling. They observed that although both cast and milled Co-Cr alloys presented a poorer corrosion resistance in artificial saliva with a more acidic pH value, the milled Co-Cr alloy had better corrosion behavior, making this alloy a better option for the prosthetic treatment of patients (Suganna et al., 2022).

The industry is always looking for new materials to make up for the deficiencies of conventional materials. The framework of a conventional RPD is often fabricated from Co-Cr or other metal materials, which has many drawbacks, such as inducing allergic reactions, esthetic issues due to the display of metal, oral galvanism, and biofilm plaque formation (Guo et al., 2022). Polyetheretherketone (PEEK) has a low specific weight allowing the fabrication of lighter metal-free RPD eliminating the risk of metallic taste and allergies to conventional RPD metal frameworks. This polymer has the quality of not changing its properties with sterilization, it does not deform at high temperatures, its elastic modulus is similar to bone, enamel and dentin, it is biocompatible, wear resistant, insoluble in water and has lower affinity for bacterial plaque compared to resin and metals. PEEK is recommended in cases where the integrity of the crowns of the abutment teeth, esthetic concerns and having an elastic modulus similar to the tooth preserves periodontal health (Peng et al., 2020). The PEEK material exhibited the highest fatigue resistance in comparison to cast and laser-sintered Co-Cr (Zheng, 2022).

Its properties make PEEK a promising material to replace metallic structures, and it can also be milled using CAD-CAM technology. An in vitro study concluded that it was possible to assert that PEEK specimens with a width of 3.00 mm, a thickness of 2.25 mm at the base, a taper of 0.5, and with an undercut of 0.50 mm exhibit the best mechanical properties (Peng et al., 2020). A review concluded that PEEK, when compared to Co-Cr, is tougher, with a chewing force that is dispersed within the mucosa and the inside of the denture, better protecting the abutment. PEEK imprinted RPD meet the needs of both the clinician and the patient because of the relatively simple method of fabrication, custom molding, convenient processing, and high material utilization (Guo et al., 2022).

Some study shows PEEK is more elastic than metal but rigid enough for clinically acceptable retention (Peng et al., 2020). But the low load at the set undercuts indicated that it was not a viable clasp material at this dimension to provide adequate retention (Zheng, 2022). Several studies demonstrated that PEEK clasps had significantly lower retentive forces of 3-10 Newton compared to Co-Cr clasps (Gentz et al., 2022).

The most challenging technical problem to resolve for full digitization of RPD treatment is the integration of a framework and artificial teeth with the denture base (Fueki et al., 2022). Husain fabric the removable partial dentures with CAD-CAM workflow and assemble all components (framework, denture teeth, denture base) without a definitive cast. Manufacture the denture framework additively by rapid prototyping using a laser beam in an SLM technique to weld the cobalt-chromium alloy powder. Denture base and artificial teeth are made of PMMA blocks in a subtractive manufacturing manner. Then, merge the denture parts with autopolymerized resin using the repositioning aids and the parallel walled framework design (Husain et al., 2020).

Another study used adhesive resin cement to bond the components (zirconia framework, PEEK) clasp, artificial teeth made of composite resin, and milled denture base made of PMMA blocks). However, the long-term durability of digital RPDs fabricated using these methods is unknown (Nishiyama et al., 2020). More studies are needed to show the usage of CAD/CAM technology in removable dental prosthesis and its benefits for the long term.

Conclusions

Use of CAD-CAM for manufacturing of removable dental prostheses has proven properties clinically acceptable, with milled, 3D printer or laser-sintered methods. Digital scanning is more efficient and more comfortable than traditional impressions. Different edentulous conditions affect the trueness of intraoral scanning, generating distortions according to the length and location of the edentulous space. Respect to PEEK, it needs to analyze its retentive force clasps used for replacement of metal frameworks. 3D printing is an additive technique that allows for cost reduction in producción of RCD. Digital dentistry allowed advantages in terms of time and cost of prosthesis with predictable results.

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