

Advantages of CAD/CAM versus Conventional Complete Dentures - A Review

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Abstract

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BACKGROUND: The introduction and evolution of CAD/CAM technology into complete dentures fabrication brought high expectations in improving disadvantages associated with conventional methods.

AIM: The purpose of this review was to analyse the existing literature on computer-engineered complete dentures and to determine their advantages over the conventional dentures.

MATERIAL AND METHODS: An electronic search of the English literature from January 1994 to March 2018 was performed in PubMed/MEDLINE, using the following keywords: CAD/CAM complete dentures, computer-engineered complete dentures, complete digital dentures, complete milled dentures, and rapid prototyping dentures.

RESULTS: A total of 179 English language titles were obtained from the database, and 14 were relevant to fulfil the purpose of this review. A review of 7 articles is summarized in 2 tables for presenting a comparison between CAD/CAM and conventional dentures in clinical and laboratory studies.

CONCLUSION: Following the review of articles that discussed the comparison between CAD/CAM and conventional complete dentures in clinical studies, it can be concluded that the main advantages of CAD/CAM dentures are the reduced clinical chair time and the number of visits, digital archiving, significantly higher retention, and more favorable clinical and patient-centered outcomes. As a result of the review of laboratory studies, superior mechanical and physical properties in CAD/CAM dentures were revealed, concerning enhanced accuracy of fit of milled denture bases, less denture tooth movement and increased toughness, ultimate flexural strength, and higher elastic modulus.

Introduction

Due to the increase in population lifespan, the need for dental treatment for edentulous people has become bigger. Despite the advancements in dental treatment possibilities for edentulism, and although implant-assisted complete dentures (CDs) are reported to be more efficient and more preferable option for edentulous patients, conventional CDs remain a choice, due to anatomical, physiological or financial restrictions [1].

Since the conventional method of fabricating CDs was established more than 80 years ago, the continuing goal was to improve all the drawbacks associated with the process of fabrication, and enhancements of the properties of polymethyl methacrylate (PMMA) material. The introduction and

evolution of computer-aided technology in the field of CD fabrication is expected to overcome the complications related to conventional CDs and to facilitate the fabrication process.

The first scientific paper on the use of a computer-aided system for designing and fabricating CDs was published by Maeda et al., in 1994, and these first CAD/CAM CDs were made by additive RP technology, from photo-polymerised acrylate material using a 3-D laser lithographic (LL) machine [2]. Since then, because of the complexity of the procedures for fabricating CDs, it took almost 20 years for the emergence of the first commercially available denture systems. Katadiyil et al., present the procedures for the production of digital CDs for the first two CAD/CAM commercial prostheses-AvaDent digital prostheses (Global Dental Science LLC, Scottsdale, Ariz.) and the Dentca CAD/CAM prosthesis system

(Dentca Inc., Los Angeles) [3]. Several researchers contribute to the development of this technology for fabrication of CDs [4] [5] [6] [7].

The process of fabricating CDs with computer-aided technology involves digitisation of the clinical information registered from the patient with light scanning technology and digital designing of CDs on computer software (CAD). The result of designing is virtual dentures in occlusion. This is followed by an automatized process of manufacturing (CAM), which can be additive (rapid prototyping) or subtractive (computerised numerical control milling) process [8]. The subtractive method is a more frequently employed method. The digital record, in the form of an STL (stereolithography) file, is stored in the database.

Beside a lot of advantages in the treatment concept and fabrication process (modified and shortened clinical protocols, digital data archive, automated fabrication of the denture bases), significant improvements in the quality of CAD/CAM CDs is expected from the enhanced physical and mechanical properties of the prepolymerized PMMA pucks (blocks), from which denture bases are milled. Preformed PMMA puck is polymerised by injection, under high temperature and pressure, which prevents shrinkage of the CAD/CAM CDs [9]. The comparison of the processing distortion of traditional techniques and the CAD/CAM fabrication technique, which leads to dimensional changes in the denture base and consequently diminished retention, stability, and support, has been dealt with in few laboratory studies [10] [11] [12].

First clinical studies related to computer-aided CD have led to the publication of a few reviews focused on clinical and patient-centered outcomes, unique applications, and clinical complications of this technology [1] [13]. The purpose of this review is to evaluate data focusing on clinical and material-related advantages of CAD/CAM CDs over the conventional CDs.

Material and methods

An electronic literature search was done through PubMed/MEDLINE database for identifying English articles with keywords "CAD/CAM complete dentures", "complete digital dentures", "computer-engineered complete dentures", "complete milled dentures", "rapid prototyping dentures" from January 1990 to March 2018. The inclusion criteria for selection were clinical studies, laboratory technical research papers, case reports, and review articles with a comparison between CAD/CAM and conventional processing techniques for CD fabrication, with specified keywords. The criteria for

excluding articles were non-English articles, and articles that failed to meet the inclusion criteria.

The search strategy involved three phases: reviewing titles, selecting abstracts of interest and final selection of articles for full-text detailed analysis. During the second phase, the abstracts that fulfil the purpose of this review were selected, and in the third phase, their full-text was analysed.

Results

The electronic search through PubMed resulted in 179 titles in the English language literature, and 14 were relevant to determine the advantages of CAD/CAM-fabricated CDs. Table 1 presents 2 articles chosen for presenting a comparison between digital and conventional CDs in clinical and patient-centered outcomes in clinical studies. Table 2 shows 5 articles from laboratory studies. Another 7 articles were selected and included in this review to contribute to the purpose of this review.

Table 1: Clinical and patient-centred outcomes

Article	Summary	Results
Kattadiyil et al., [14]	This comparative prospective study compared digitally and conventional CDs fabricated by predoctoral students with faculty supervision; each of 15 completely edentulous patients (average age 55 years) received 1 conventional and 1 digital (AvaDent) set of CDs.	Significantly higher average scores were recorded for the digital CDs; Students preferred digital CDs compared with conventional; The conventional fabrication process required significantly more clinical time.
Al Helal et al., [18]	This clinical study compared conventionally processed denture bases (20 CAD/CAM (AvaDent) and N). 20 conventional (heat-polymerised) processed maxillary denture bases were fabricated for individuals with completely edentulous maxillary arches; for measuring the retention, with custom-designed testing device, each denture base was vertically pulled by using an advanced digital force gauge 3 times at 10-minute intervals.	Significantly increased retention values were observed for the milled denture bases (an increase of 19,91 values were observed for the milled denture bases).

Discussion

Encouraging advances in computer-aided in the field of CD fabrication have increased the interest and the number of publications in the last few years. 14 articles were selected to accomplish the purpose of this review, to evaluate the data only focusing on the advantages of CDs fabricated with CAD/CAM technology in comparison to conventional CDs. However, long-term clinical outcome studies are also necessary to be performed.

One of the first advantages that are reported from utilising CAD/CAM technology for the fabrication of CDs is the reduced number of appointments and simplified laboratory work in comparison to the conventional protocol [14].

Table 2: Laboratory findings

Article	Summary	Results
Goodacre et al., [10]	Comparison of the denture base adaptation of conventional (pack and press, pour, injection) and CAD/CAM techniques for fabricating CDs; 40 duplicated gypsum casts were created, and laser scanned; 10 specimens for each of the 4 techniques had been fabricated, hydrated for 24 h, and the intaglio surface laser scanned; using surface matching software, the scan file of each denture was superimposed on the scan file of the corresponding cast; measurements were made at 60 locations, providing evaluation of fit discrepancies at 5 areas; accuracy and reproducibility were assessed.	The CAD/CAM technique showed the best combination of accuracy and reproducibility;
Srinivasan et al., [11]	Comparison of trueness of CAD/CAM milled CDs with injection-molding and conventionally (flask-pack-press) manufactured CRDPs; 33 CDs were fabricated by three different technique, using a single master reference model; and incubated in artificial saliva for 21 days; scanning of the intaglio surface was performed 7 days after processing, and again after 21 days in artificial saliva; the corresponding surfaces of the reference model and the 3D images of the dentures were super-imposed using a 3D-software; 5 specific regions of interest were defined and compared.	At baseline, there was no difference in the trueness of the total intaglio surfaces between the groups; after 21 days in artificial saliva, only CDs showed significant trueness; improved trueness for all techniques in most regions of interest.
Goodacre et al., [19]	Comparison of the denture tooth movement of pack-press, fluid resin, injection, CAD/CAM bonded, and CAD/CAM monolithic techniques; 50 dentures (10 for each technique); preprocessing and postprocessing scan files of the cameo surface of each denture were superimposed using surface-matching software; measurements were made at 64 locations, and tooth movement in a buccal, lingual, mesio-distal, and occlusal direction were evaluated.	The CAD/CAM monolithic technique was the most accurate and the most reproducible technique.
Steinmassl et al., [20]	Comparison of methacrylate monomer release between CAD/CAM dentures (4 different CAD/CAM denture systems: Baltic Denture Systems, Vita VIONIC, Weiland Digital Dentures, Whole You Nexteeth) and conventional (heat-polymerised) dentures; denture weight, volume, and density were determined; after 7 days of water storage, the monomer release was measured by high-performance liquid chromatography.	No significant difference in released monomer between CAD/CAM and the conventional dentures.
Srinivasan et al., [21]	An in vitro evaluation and comparison of biocompatibility, mechanical properties, and surface roughness of a pre-polymerized PMMA resin for CAD/CAM CDs and a traditional heat-polymerized PMMA resin; ultimate Biocompatibility was assessed with cultivation of two types of cells (human primary osteoblasts and embryological mouse fibroblasts) on the substrate separately; mechanical properties were tested with the nanoindentation test, three-point bending test, and surface roughness test.	The tested CAD/CAM and heat-polymerised resins were equally biocompatible; CAD/CAM resins demonstrated improved mechanical properties (higher elastic modulus, ultimate strength, and toughness); higher roughness of the CAD/CAM resin specimens.

Kattadiyil et al., in their study compared the use and effectiveness of CAD/CAM technology in digital CDs fabrication (AvaDent digital CD protocol) with those of the conventional method. Apart from the reduced number of visits to patients for the digital protocol (2 visits), they also emphasise the significantly reduced clinical treatment time for digital fabrication process (approximately 3.5 hours less compared to the conventional protocol). Besides that,

clinical evaluation by faculty in this study determined significantly higher retention, fit, and stability in digital CDs; significantly higher average patient response scores were recorded for the digital CDs regarding comfort, retention, masticatory efficiency, and efficiency of the technique. In the clinical retrospective study of Saponaro et al., the average number of visits for the digital protocol was 2.39 (some patients required a third visit) [15] [16]. Still, not every CAD/CAM denture system is intended for a 2-appointment protocol. In the pilot study of Schwindling and Stober, digital CD fabrication with the Weiland Dental system was intended for 4 clinical visits (including a trial placement visit), but a mean of 5.4 visits was needed to complete the fabrication process [17]. The improved retention of digital CDs could be explained by the improved fit and due to the absence of polymerisation shrinkage and the unique method of milling the digital dentures from a prepolymerized block of acrylic resin [14]. In the clinical study of AlHelal et al., the retention values of maxillary conventional heat-polymerised denture bases were compared with digitally milled denture bases, after 24 h storage in water before the testing appointment [18]. The clinical result showed a significant increase in retention for the digital CDs compared with the conventional group. This result indicated that the hydration might not have sufficiently compensated for the polymerisation shrinkage. AlHelal suggested that possible explanation for this could be the increased density of prepolymerized acrylic resin block, which offers higher dimensional stability and is not necessarily influenced by hydration.

A great additional advantage for the digital technique is emphasised, and that is the electronic archiving of all clinical data from the patient, together with the design of the manufactured prostheses, which enables making spare or new prostheses, in case of breaking or losing them, without clinical appointments.

Few laboratory studies have compared the processing distortion of traditional techniques and the CAD/CAM fabrication technique [10] [11] [12]. The results of Goodacre et al., laboratory study indicate that the CAD/CAM processing technique offers a desirable balance of minimal fabrication distortion and better adaptation. They found that CAD/CAM fabrication process is the most accurate and reproducible denture fabrication technique in comparison with traditional techniques [10]. Although Srinivasan et al., in their comparative study have concluded that the trueness of the intaglio surface of all three investigated techniques seems to remain within a clinically acceptable range, they reported that CAD/CAM group showed the strongest compression (with the exception of the tuberosities), especially in the vestibular flange area [11]. The compression in the area of the vestibular flange (tighter inner seal) might be related to improved retention in the findings of the clinical studies. They noted that an edentulous

ridge was chosen without pronounced undercuts and with a shallow palate, and if the palate or the tuberosities been steeper, the shrinkage during heat polymerisation would have probably increased the misfit of the intaglio surface. The results of the in vitro study of Steinmassl et al., designed to evaluate the denture fit in a clinically relevant setting, have supported the findings in Goodacre study [12]. The total number of examined, currently available, CAD/CAM dentures has had a significantly higher precision of denture base fit than the conventional dentures.

The least denture tooth movement during processing with the least denture base distortion at CAD/CAM milled dentures were the combined results of both laboratory studies of Goodacre et al., [10][19]. Accordingly, the CAD/CAM technique would be considered the best processing technique in comparison with traditional techniques. Results of their study for denture tooth movement demonstrated that techniques requiring compression during processing (pack-and-press, injection) showed increased positive occlusal tooth movement compared with techniques not involving compression (fluid resin, CAD-CAM bonded, CAD-CAM monolithic), meaning that it would cause an increase in the patient's OVD. Clinical relevance of these findings might be less laboratory and clinical post-insertion adjustments [16].

Although CAD/CAM dentures are assumed to have a lower methacrylate monomer release than conventionally fabricated dentures, the results from the laboratory study of Steinmassl et al., have not proved that hypothesis [20]. None of the four evaluated different CAD/CAM dentures have released significantly less monomer than conventional (heat-polymerised) dentures. As one of the conclusive explanation for no significant differences, they point out on bonding agents (methacrylate-based) used for fixation of the denture teeth to the milled sockets in CAD/CAM dentures, as a source of methacrylate monomer release.

The claims for superior mechanical properties of the pre-polymerized PMMA pucks were substantiated in the laboratory study of Srinivasan et al., [21]. The increased toughness, ultimate strength, and higher elastic modulus may provide clinical benefits, both for patients and clinicians, regarding designing the denture base with lower minimal thickness, without a common occurrence of denture fractures. However, these claims need to be verified in a clinical study.

In conclusion, based on the published literature, this review has drawn some advantages of the CAD/CAM dentures compared to conventionally fabricated dentures. The main advantages reported in the selected clinical studies were the reduced clinical chair time and number of visits, digital archiving, significantly higher retention, and more favourable clinical and patient-centered outcomes of CAD/CAM

dentures. The laboratory studies revealed superior mechanical and physical properties in CAD/CAM dentures, regarding the enhanced accuracy of fit of milled denture bases, less denture tooth movement and increased toughness, ultimate strength, and higher elastic modulus. Long-term clinical research and additional material-related aspects are warranted to reach definitive conclusions.

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