Assessment of the fit of removable partial denture fabricated by computer-aided designing/computer aided manufacturing technology

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ABSTRACT

الأهداف: ثبات أطقم الأسنان المتحركة التقليدية يظل مشكلة، لكن الأطقم المتحركة المصممة بتقنية حاسوبية قد توفر ثبات أفضل. هذه المراجعة تهدف إلى تقييم مستوى الدليل الذي يدعم فكرة جودة الثبات لأطقم الأسنان المتحركة الجزئية المصممة بالكاد / كام و الطباعة الثلاثية الأبعاد.

الطريقة: تم إجراء بحث في جوجل سكولار، بابميد ومكتبة كوكرين بإستخدام مشغلات بوليان. كل المقالات المنشورة باللغة الأنجليزية و التي نشرت منذ العام 1950 و حتى أبريل 2017 أعتبرت مقبولة للدخول في هذه المراجعة. العدد الإجمالي للمقالات التي إحتوت على مصطلحات البحث في أي جزء منها تم الإطلاع عليها و كان عددها 214 مقالة. بعد إستثناء المقالات الغير متعلقة أو المتكررة تبقت 12 مقالة أدخلت في هذه المراجعة المنهجية.

النتائج: كل الدراسات المضمنة في المراجعة كانت تقرير حالة ما عدا دراسة واحدة كانت مجموعة من عشر حالات مرضية. الفحص البصري و اليدوي سواء في الموديل أو في فم المريض كان أكثر الطرق المستخدمة لتقييم الثبات للأطقم المتحركة الجزئية. دراسة واحدة فقط قيمت ثبات الأطقم بإستخدام مادة التسجيل السليكون. هذه المراجعة وجدت أن الغالبية العظمى من الدراسات المضمنة في المراجعة وجدت درجة الثبات للأطقم المتحركة الجزئية تتراوح بين الكافيه إلى الممتازة.

الخاتمة: بالرغم من نقص التجارب الإكلينيكية التي تقدم الدليل العلمي القوي، يظل الدليل المتوفر حالياً يدعم الإدعاءات بجودة ثبات الأطقم المتحركة الجزئية المصممة بالتقنيات الجديدة المعتمدة على الكاد / كام.

Objective: To assess the level of evidence that supports the quality of fit for removable partial denture (RPD) fabricated by computer-aided designing/computer aided manufacturing (CAD/CAM) and rapid prototyping (RP) technology.

Methods: An electronic search was performed in Google Scholar, PubMed, and Cochrane library search engines, using Boolean operators. All articles published in English and published in the period from 1950 until April 2017 were eligible to be included in this review. The total number of articles contained the search terms in any part of the article (including titles, abstracts, or article texts) were screened, which resulted in 214 articles. After exclusion of irrelevant and duplicated articles, 12 papers were included in this systematic review.

Results: All the included studies were case reports, except one study, which was a case series that recruited 10 study participants. The visual and tactile examination in the cast or clinically in the patient's mouth was the most-used method for assessment of the fit of RPDs. From all included studies, only one has assessed the internal fit between RPDs and oral tissues using silicone registration material. The vast majority of included studies found that the fit of RPDs ranged from satisfactory to excellent fit.

Conclusion: Despite the lack of clinical trials that provide strong evidence, the available evidence supported the claim of good fit of RPDs fabricated by new technologies using CAD/CAM.

Saudi Med J 2018; Vol. 39 (1): 17-22
doi: 10.15537/smj.2018.1.20796

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Disclosure. Authors have no conflict of interests, and the work was not supported or funded by any drug company.

The fit of conventionally fabricated removable partial dentures (RPDs) has been identified as the chief complaint of RPD wearers.[1] A well-fitting RPD can be investigated clinically by mirror and explored when rest seats are properly seated, the metallic component touches the teeth, and the oral tissues are not impinged on by any part of the RPD, such as the major connectors.[2] In a study conducted by Dunham et al[3] approximately 79% of the RPDs showed no optimal contact in the rest seats. Furthermore, they found that 21% of the rests had no contact at any point.

Pioneer studies examined the fit of RPDs fabricated by recent technology, including computer-aided designing/computer aided manufacturing (CAD/CAM); in addition to rapid prototyping (RP), they showed promising results.[4] Such techniques have been used widely in oral and maxillofacial surgery.[5] In dentistry, the application of the CAD/CAM technology started with fabrication of crowns and bridges in the early 1980s;[6] however, there is little literature exploring the usage of this technology in the fabrication of RPDs, possibly because of the lack of properly designed software and the technical problems associated with metal casting.

The significant benefits of using CAD/CAM and 3-dimensional printing technology in the fabrication of RPDs include surveying the cast digitally to identify wanted and unwanted undercuts and production of virtual patterns of the RPDs' frameworks. Quality control factors could be built into software, such as modification of the scaling factor to compensate for the shrinkage that occurs during casting.[7]

Recent feasibility studies by William et al[7] and Eggbeer et al[8] have set the technical methodology of digital scanning and surveying of casts, computer-aided designing of RPD framework, and use of RP in the production of patterns. Recently, much CAD/CAM software has become commercially available for designing RPD framework, with an additional RP technology that produces a physical 3D element. The master printed pattern can be casted directly in metal alloy or by using conventional casting techniques. This new technology can improve the quality of fit of RPDs in addition to reducing the labor in the dental laboratory.

This review aimed to assess the level of evidence that supports the quality of fit for RPDs fabricated by CAD/CAM and RP technology.

Methods. *Keywords and search strategy.* The keywords and search strategy used in this review are shown in the summary of search findings in **Table 1**. All steps of the systematic review (identification, screening, eligibility, and inclusion) are described in **Figure 1**. This systematic review was registered in PROSPERO on 4th July 2017 with the number CRD42017069921.

Table 1 - Summary of search results.

Search engine	Search terms	Papers
Google Scholar	(CAD or CAM or CAD/CAM or computer aided or prototyping or rapid manufacture or electronic surveying or digitized casts) AND (removable partial denture)	107
PubMed	(CAD or CAM or CAD/CAM or computer aided or prototyping or rapid manufacture or electronic surveying or digitized casts) AND (removable partial denture)	103
Cochrane library	Removable partial denture AND computer aided	4
Total	Titles and abstracts examined Papers excluded Full texts retrieved Papers included in the review	214

Limits activated: English language (searched 8 May 2017).
CAD - computer-aided designing, CAM - computer aided manufacturing

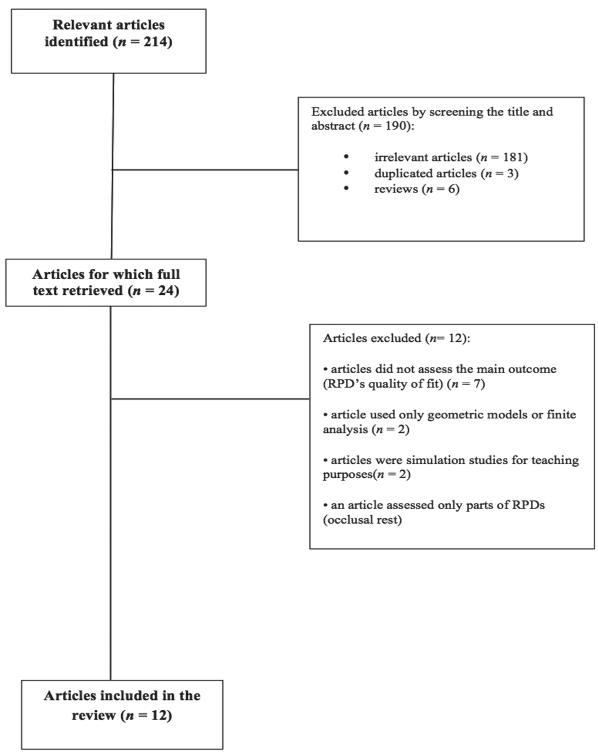

Figure 1 - Flow diagram of the included studies in the systematic review. RPD - removable partial denture

Table 2 - Summary of findings.

Study design	Sample size	Three-dimensional scanning	CAD of the RPD framework	Surveying	Removing unwanted undercuts	Pattern manufacture	Casting	Finishing	Method of outcome assessment (RPD fit)	Quality of fit	Ref.
Case series	348 measurements in the casts of 10 participants	Laboratory scanner	Free Form software	Done	Not reported	Printed in resin using RP	Conventional method, using heat polymerized resin and artificial teeth	Not reported	Internal fit assessed by silicone registration material	Internal discrepancy detected	13
In vitro feasibility case report	A study cast of maxillary arch	Laser scanning system with several scanning views, which were used to gather cloud data	The CAD software has the ability to demarcate the upward- and downward-facing surfaces	Done	Unwanted undercuts were removed	Manufacturing of sacrificial frameworks using RP	A high-temperature-resistant phosphate investment material was used	Not reported	Clinically assessed	Satisfactory	14
Case report	A 46-year-old woman with limited mouth opening	Intraoral video scanning system with several scanning views, which were used to gather cloud data	3ShapeDental System, 3Shape	Done	Unwanted undercuts were removed	Fabrication of polymerized cast using RP	Fabricated the titanium alloy using an SLM machine	Not reported	Clinically assessed	Excellent quality of fit	16
Case report	A 63-year-old partially edentulous woman	Open source intraoral scanner	Free Form software	Not reported	Not reported	Printed using RP (3D printing)	Cast in a cobalt chromium alloy with conventional casting techniques	Done	Clinically assessed	Accurate fit	17
Case report	Stone cast	Structured-light 3D scanner,	Direct use of the 3D cast mesh as a medium for CAD modeling and building of the RPD framework	Done	Unwanted undercuts were removed	3D printing machine	Framework generated from polymer power at 70 watt to sinter the polymer into a solid form	Not reported	Visual examination	Accurate fit of framework	11
Case report	A female patient	Structured white-light digitizer	Free Form software	Done	Not reported	Manufacturing of sacrificial frameworks using RP	The pattern was casted directly as cobalt–chromium alloy	Done	Clinically assessed	Framework fitted satisfactorily	9
Case report	A partially edentulous patient	Structured white-light digitizer	Free Form software	Done	Unwanted undercuts were removed	Four RP techniques were studied: perfactory A, stereo lithography, ThermoJet A, Solid scape A	Patterns casted as chromium–cobalt alloy	Done	Clinically assessed	Satisfactory	7
Clinical report	A 41 yr old woman and a 45 yr old man	intraoral scanner; and a digital impression of the opposing arch	Designed by traditional technique (not CAD/CAM)	done	Not reported	Fabricating pattern of RPD framework by RP	cobalt-chromium RPD manufactured after using conventional casting methods	Not reported	Clinically assessed	Satisfactory	15
Case study	Stone cast	3D optical digitizer	Geometric model of the RPD framework fabricated using CAD/CAM	done	Not reported	No manufacturing	No casting	_	Visually assessed	Good fitting	12
Case study	Stone cast	Three-structured white-light digitizer, several scanning views used to gather cloud data	Free Form, software	Not reported	Not reported	SLM technology	A stainless steel and chrome cobalt alloys were compared	Not reported	Clinically assessed	Excellent fit of cobalt chrome framework	10
Case report	75-year-old woman	Structured white-light digitizer, several scanning views used to gather cloud data	Free Form software	Done	Not reported	SLM technology	Chromium cobalt	Done	Clinically assessed	Excellent fit	8
Case report	Stone cast	Not reported	Free Form software	Not reported	Not reported	Fabricating pattern of RPD framework by RP	Not reported	Done	Assessed in the cast	Satisfactory	18

CAD - computer-aided designing, CAM - computer aided manufacturing, RPD - removable partial denture, RP - rapid prototyping, SLM - selective laser melting, 3D - 3 dimensional,

Eligibility criteria. All articles published in English and published from 1950 until April 2017 were eligible to be included in this review. The total number of articles containing the search terms in any part of the article (including titles, abstracts, or article texts) were screened, which resulted in 214 articles. The irrelevant studies were excluded based on their titles and abstracts, which resulted in exclusion of 187 articles. In the remaining 27 articles, 3 articles were duplications found in both PubMed and Google scholar. The full texts were retrieved for the remaining 24 articles to identify the finally included studies. Twelve articles were excluded with justification based on the full text review as follows: (i) Seven articles did not assess the main outcome (RPD's quality of fit). (ii) Two articles used only geometric models or finite analysis. (iii) Two articles were simulation studies for teaching purposes. (iv) One article assessed only one part of RPDs (occlusal rest).

Data sources. An electronic search was performed in Google Scholar, PubMed, and Cochrane library search engines, using Boolean operators. The bibliographies of retrieved papers were screened for more articles that were relevant. The search strategy used is demonstrated in **Table 1**.

Data extraction. To ensure that the extraction of all required information regarding certain properties of bulk-fill composite was achieved properly, 2 reviewers read the included studies. The data were collected in data extraction form, shown in **Table 2**, and included the following items. Study design; Sample size; Three-dimensional scanning; CAD of the RPD framework; Surveying; Removing unwanted undercuts; Pattern manufacture; Casting and Finishing; Method of outcome assessment of fitting; and Fitting outcome.

Results.

Three-dimensional scanning. Many included studies.[7-10] used a structured white-light digitizer, which scanned the partially edentulous cast. Other studies used scanning techniques, such as a structured-light 3D scanner,[11] to scan the cast. In addition, a 3D optical digitizer, laboratory scanner, and laser scanning system were used to obtain 3D scans of a plaster cast.[12-14] Multiple scans were overlapped to collect point cloud data, which have been organized by other software, such as Poly works, that could be exported in STL file format to CAD/CAM. Intraoral scanning systems included intraoral scanners,[15] by which the full digital impression of both arches can be made. In addition, an intraoral video scanning system was used[16] for patients who had limited mouth-opening ability, and an open-source intraoral scanner was used[17] that could scan the hard and soft tissues of the maxillary arch.

CAD of the RPD's framework and surveying. The majority of included studies[7-10,13,17,18] used Free Form software for CAD of RPD frameworks. This software uses a haptic interface and incorporates 3-dimensional positioning, which allows the movement and rotation of all axes. It can transport the hand motions into the virtual environment. A study by Wu et al[16] used the Shape Dental System software in CAD for the RPD frameworks because of its ability to construct complicated frameworks. In a study by Hussein and Hussein,[11] an engineering software was used to design RPDs.

Most studies[7-9,11-16] reported survey of the undercuts. The CAD program had an ability to demarcate up and down-directed surfaces; thus, areas of wanted and unwanted undercuts could be identified in a different color from the buck model. In spite of this, only some studies[7,11,14,16] reported the elimination of unwanted undercuts based on the path of withdrawal.

Pattern manufacturing, casting, and finishing. Rapid prototyping (stereolithography) was used for printing resin patterns.[7,9,11-14,16-18] Rapid prototyping development of the laser melting technique[8,10] for manufacturing of metallic patterns directly was used by Williams et al[6] in 2006. Casting was achieved by the conventional method of using heat-polymerized resin and artificial teeth.[11,13-15,17,18] On the other hand, casting was carried out directly by CAM techniques such as 3D printing technology when titanium alloy RPD framework was fabricated.[7-10,16] Finishing of the metal RPD framework was reported to be conducted in a conventional manner.[7-9,17]

Assessment of quality of the fit. The visual and tactile examination of the cast or clinically in the patient's mouth was the most-used method for assessment of the fit of the RPD.[7-12,14-18] Lee et al[13] assessed the internal fit between RPD and oral tissues by using silicone registration material. The fit of RPDs was found excellent or accurately well fitted in some studies.[8,11,16] In a study by Bibbet al[10] the RPDs fabricated of cobalt chrome had excellent clasping fit. The fit was described to be satisfactory or good-fitting,[7,9,12,14,15] whereas RPDs were sometimes described as just fitting.[17,18] Lee et al[13] reported that the internal discrepancy was in the fitting of RPDs.

Discussion.

The advantages claimed for introduction of digital technology in the field of removable partial prostheses include reduction of time for fabrication, improved quality assurance issues, and improved fit. The aim of this review was to investigate the scientific evidence supporting the claims of improved fit associated with using digital technologies such as 3-dimensional scanning, CAD/CAM, and RP.

All the included studies were case reports, except one study that was a case series that recruited 10 study participants.[13] The strength of the scientific evidence that was produced by case reports or case series is known to be the lowest among all epidemiological studies.[19] However, the search conducted by this review did not result in any clinical trial in the field of digital fabrication of RPDs. This field has recently been studied, and many of the included studies were feasibility studies exploring the ability to use CAD/CAM and 3-dimensional printing technologies in designing and manufacturing RPDs frameworks. Because the fabrication of RPDs is a complex process and time consuming, introduction of these new technologies may provide faster production of, and more accurate, RPDs.

The findings of this review showed that all included studies, except the study of the case series conducted by Lee et al,[13] found that the fit of RPDs ranged from satisfactory to excellent fit. Lee et al[13] used silicon registration material to assess the quality of fit instead of the visual and tactile examination used in other studies. This method of fit assessment is faulty and inaccurate because it assessed the internal fit between oral tissues and RPDs while ignoring other important criteria such as proper seating of rest seats and optimal contact between teeth and metallic components.[2]

Studies reporting excellent or accurate fit[8,10,11,16] mainly used a structured white-light digitizer as a technique by 3-dimensional scanning. Generally, the accuracy of a digital impression, as a new technique, was studied and found to be, up to 10 micrometer, as reliable as that measured in conventional plaster casts.[20] These studies used different techniques for framework CAD, including Free Form, 3-Shape Dental System, and engineering software. This suggested a less-important role of software for framework designing in quality of fit. However, most studies that found excellent or accurate fit reported surveys of undercuts or removal of unwanted undercut areas.[8,11,16] This is in agreement with the current evidence about the importance of survey and removal of unwanted undercuts in the quality of fit of RPDs.[21] Regarding pattern manufacturing and casting of RPDs, RP used for production of sacrificial resin patterns in studies reported excellent, accurate, or satisfactory fit of RPDs. However, studies using a laser melting technique for manufacture of metallic patterns reported excellent fit of RPDs.

Study limitations. The lack of controlled clinical trials in which the CAD/CAM-fabricated RPDs were compared to conventionally fabricated ones. This could allow for investigation of significant differences in the quality of fit between the 2 comparison groups. Another limitation is the absence of technical comparisons between different software used for the same purposes in terms of accuracy, reliability, and measurement errors.

In conclusion, despite the lack of clinical trials that provide strong evidence, the available evidence supports the claim of good fit of RPDs fabricated by CAD/CAM and 3-dimensional printing technologies. Most included studies reported excellent fit, characterized by the use of a white-light digitizer as a technique for 3-dimensional scanning, or the laser melting technique for manufacture of metallic patterns.

The clinical implications. The findings of this review provide evidence for the quality of fit associated with RPDs fabricated by computerized technology. Recently, digital scanning and rapid prototyping are used in different field of industry to yield more accurate designing results. The introduction of such accurate techniques to the field of prosthodontics can result in more accurate frameworks and designs of RPDs with subsequent improved quality of fit. The better quality of fit of RPDs, the more comfortable and functioning dentures. Moreover, using computerized techniques can reduce time of laboratory fabrication of RPDs making them available for patient use faster than conventional techniques.

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