Review Article

Comparative evaluation of the marginal fit of computer-aided design-computer aided manufacturing fabricated crowns from direct and indirect digital impression – A systematic review

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Abstract

The accuracy of the digital impression method is responsible for fabricating crowns with adequate marginal fit which in turn determines the postendodontic prognosis. This systematic review was undertaken to identify the influence of the two digital impression techniques in producing full coverage crowns with better marginal fit. This systematic review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-analysis statement. A detailed search was done in electronic databases (PubMed, EBSCOhost, LILACS, Cochrane) along with hand searches of reference articles. In vivo crossover studies comparing the marginal fit of the computer-aided design-computer-aided manufacturing (CAD-CAM) fabricated crowns from direct and indirect digital impressions published from inception till July 2023 were included in this review. The quality assessment of the included articles was done based on a modified Cochrane collaboration tool for crossover studies. A total of 280 articles were identified, after duplicate removal, title and abstract screening, and full-text evaluation, 7 articles were included in this systematic review. The overall quality of evidence is moderate. The CAD-CAM crowns fabricated from direct digital impressions exhibited a better marginal fit than those crowns fabricated by indirect digital impressions. The overall quality of evidence is moderate. Further clinical studies has to be conducted for evaluating the latest technologies towards achieving the misfit of zero.

Keywords: Crown; direct digital impression; indirect digital impression; marginal fit

INTRODUCTION

The structural integrity of the teeth decreases after endodontic access cavity preparation, causing cuspal deflection during function and thereby increasing the possibility of cuspal fracture and microleakage at the margins of restorations.[1] During a conservative access preparation, the fracture resistance of the teeth reduces by around 5%, when the tooth is associated with occlusal caries, it is reduced by 14%–44%, and if there is loss of marginal ridge/ridges it further reduces up to 63%.[2] A definitive restoration involving the cusps should be placed as soon as possible after the completion of the root canal treatment. These cuspal coverage restorations are advocated to reinforce the remaining tooth structure to prevent tooth fracture.[3] Full coverage crowns have been considered as a viable option for restoring endodontically treated teeth.[3] The important

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factor to be addressed during the fabrication of these full crowns is their marginal fit.[4]

Structured question:

Is the dimensional accuracy of the digital impressions acquired from direct intraoral scanners superior to those obtained from indirect laboratory scanners for fabricating crowns by CAD-CAM method?

PICO analysis:

Population (P) – Adult patients requiring crowns in the posterior tooth region

Intervention (I) – Digital impression obtained through intraoral scanner

Comparison (C) – Digital impression obtained through laboratory scanner

Outcome (O) – Marginal fit of the crowns fabricated by CAD-CAM method

Study (S) – *In vivo* studies.

Ill-fitting margins of full crowns lead to cement dissolution facilitating microbial accumulation and plaque retention causing periodontal problems and secondary caries resulting in failure.[5] Hence, for the success and longevity of the endodontically treated teeth establishment of an adequate coronal seal with adequate cuspal coverage is of prime importance.[6] With the drift toward the use of computer-aided design-computer aided manufacturing (CAD-CAM) for the fabrication of the crowns, obtaining a precise digital impression of the prepared tooth is a crucial step and it can be obtained either directly via intra-oral scanners or indirectly through laboratory scanners. An impression method having a perfect match of the prepared tooth with a misfit of zero would indicate the ideal precision and increasing values from zero would indicate poorer precision.[7]

Laboratory scanners are being used for digital impressions but the misfit of zero is not yet achieved. Attempts have been made to reduce the errors occurring with indirect digital impressions by direct digital scanning with intraoral scanners developed to standardize the impression making and to optimize the restoration quality as well as workflow efficiency and patient comfort.[8] Intraoral scanners produce a 3D virtual model which can be directly used by the CAD-CAM systems. Although different systems use different technologies all the systems have the same purpose, i.e., to obtain a 3D virtual model by digitalizing the patient's mouth, and definitive restorations are designed and fabricated based on these virtual models.[9] The efficacy of these intraoral scanners in doing so has to be evaluated.

Therefore, the aim of this systematic review is to evaluate the marginal fit of CAD-CAM fabricated full coverage crowns with the digital impressions acquired from direct intraoral scanners compared with those from indirect laboratory scanners. The null hypothesis formulated is that there will be no difference in the marginal fit and dimensional accuracy of the CAD-CAM fabricated crowns from direct and indirect digital impressions.

METHODOLOGY

This systematic review was conducted according to the guidelines of Preferred Reporting Items for Systematic Review and Meta-analysis.[10] The protocol for this systematic review was registered in the PROSPERO database (Registration number: CRD42023472725). The PICO formulated was as follows:

Literature search

For identifying studies to be included in this review, a detailed search strategy was developed with MeSH terms based on the PICO question. Article search was done from inception till July 2023 in electronic databases (PubMed, Cochrane, EBSCOHost, Lilacs) along with hand search of relevant articles.

Inclusion criteria

- *In vivo* cross-over studies published in the English Language
- Patients requiring a single crown in the posterior region
- Studies comparing the intraoral scanner with the laboratory scanner
- Evaluation of marginal fit by replica method.

Exclusion criteria

- *In vitro* studies performed on typodont, extracted teeth, animal samples
- Studies comparing the two modalities based on full arch measurements
- *In vivo* studies involving implant abutments
- Letter to the editor, case reports, descriptive studies.

Data collection

One reviewer independently screened the title and abstract of the resultant articles according to the inclusion and exclusion criteria. The full texts of the eligible articles were screened completely to confirm inclusion in this review. The following details associated with the study were acquired: title of the study, author, year of publication, intraoral scanner used, type of impression material used, type of material used to fabricate the cast, extraoral scanner used, method of evaluation of the marginal fit, magnification used for evaluation, and results. All the collected data are tabulated.

Quality assessment and risk of bias

The risk of bias among the included studies was evaluated using a modified tool suggested in the Cochrane Handbook for systematic reviews proposed by Ding *et al*., in 2015.[11] The quality assessment tool comprises nine domains postulated for assessing the cross-over studies. The checklist evaluates the methodological aspects through questions answered as "high," "unclear," or "low." "High" was given when the included study answered the criteria, "Unclear" was given when the criteria were not mentioned in detail, and "No" was given when the study failed to answer the criteria. When >7 criteria are fulfilled then the article is rated as "low risk of bias," when 4–7 criteria are fulfilled then it is rated as "moderate risk of bias," when <4 criteria are fulfilled then it is rated as "high risk of bias."

RESULTS

A flowchart describing the selection process is presented in Figure 1, electronic database searches with defined MeSH terms retrieved a total of 339 publications and in addition, 3 articles were identified through manual screening of publications relevant to the title making a total of 342 articles. After the removal of duplicates, a total of 271 articles remained which were subjected to title and abstract screening and resulted in a total of 14 articles. The full texts of these 16 articles were examined based on the inclusion and exclusion criteria which revealed a total of 7 articles eligible for this review.

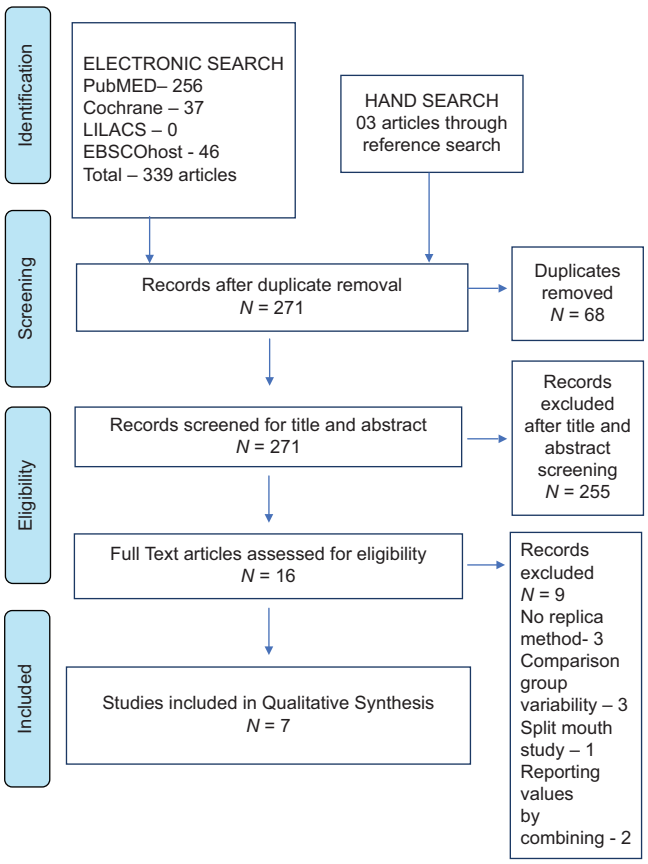

Figure 1: Preferred Reporting Items for Systematic Review and Meta-analysis flowchart

Studies excluded after full text assessment (with criteria for exclusion)

1. Bosniac *et al*., 2019[12] – Study group values were combined
2. Hategan *et al*., 2018[13] – No control conventional impression group
3. Schubert *et al*., 2020[14] – Replica method was not followed
4. Haddadi *et al*., 2019[15] – Split mouth study
5. Park JS *et al*., 2020[16] – Study group values were combined
6. Berrendero *et al*., 2019[9] – Replica method was not followed
7. Brawek *et al*., 2013[17] – No control conventional impression group
8. Sanchez-Lara *et.al*., 2023[18] - CAD-CAM crowns were not fabricated for conventional impression group
9. Liu *et al*., 2022[19] - Replica method was not followed

Study characteristics

A total of seven studies met the eligibility criteria and were included in this systematic review. Data were extracted regarding the title, author and year, types of interventions, and comparison, evaluating the marginal fit by replica method under various levels of magnification. The studies used various direct and indirect digital scanners namely LAVA C.O.S, Heraeus cara TRIOS, Omnicam, Truedefinition, EZIS PO, i500, CS3600 direct digital scanners, and LAVA SCAN ST, D700, E1 indirect digital scanners. The results are summarized in Table 1.

Quality assessment and risk of bias

The quality assessment of the included crossover studies was evaluated based on the modified Cochrane collaboration tool proposed by Ding *et al*., in 2015.[11] Based on this assessment, 3 of the included articles scored high in randomization of treatment order and allocation concealment, all the studies scored unclear in unbiased data category, 2 scored high and 3 scored unclear in terms of blinding. In the remaining categories, all the included studies scored low. The quality assessment of the included articles is summarized in Table 2 and depicted in Figure 2.

Certainty assessment

For assessing the body of evidence qualitatively, the grades of Recommendation, Assessment, Development and Evaluation (GRADE) concept can be used. Since no meta-analysis was performed in this review, recommendations by assessment cannot be derived. Hence, the usage of the GRADE tool for evaluating the body of evidence did not seem appropriate.

Table 1: Characteristics table

Title	Author and year	Intervention	Comparison	Evaluation of marginal fit	Result
Clinical evaluation of all-ceramic crowns fabricated from intraoral digital impressions based on the principle of active wavefront sampling	Syrek *et al.*, 2010[20]	Lava C.O.S with titanium dioxide powder	Impression – Addition silicone Cast – Type IV plaster Scan – Lava scan ST	Replica method under ×66 optical magnification	I – median - 49 mm (Q1: 32 mm; Q3: 65 mm) C – median - 71 mm (Q1: 45 mm; Q3: 98 mm)
Influence of conventional and digital intraoral impression on the fit of CAD/CAM fabricated all-ceramic crowns	Berrendero *et al.*, 2015[24]	Heraeus cara TRIOS	Impression – addition silicone Cast – Type III plaster Scan – D700, 3shape	Replica method under ×40 magnification	I – mean – 106.6±69.6 µm C – D700 – mean – 119.9±59.9 µm
Evaluation of fit and efficiency of CAD/CAM fabricated all-ceramic restorations based on direct and indirect digitalization: a double-blinded, randomized clinical trial	Ahrberg *et al.*, 2015[21]	Lava C.O.S with titanium dioxide powder	Impression – polyether Cast – Type IV plaster Scan – Lava Scan ST	Replica method under ×66 optical magnification	I – mean - 61.08 µm (SD 24.77 µm) C – mean - 70.40 µm (SD 28.87 µm) $P<0.05$
Accuracy of single-tooth restorations based on intraoral digital and conventional impressions in patients	Boeddinghaus *et al.*, 2015[22]	1 - Heraeus cara TRIOS (Ctrios) 2 - Sirona CEREC AC Omnicam (Ocam) 3 - TDef	Impression – polyether Cast – Type IV plaster Scan – D700, 3shape	Replica method under ×40 magnification	I1 – Ctrios – median - 112 µm (94–149 µm) I2 – OCAM - median - 149 µm (114–218 µm) I3 – Tdef - median - 88 µm (68–136 µm) C – D700 – median - 113 µm (81–157 µm)
A clinical evaluation comparing the fit of all-ceramic crowns obtained from silicone and digital intraoral impressions based on wavefront sampling technology	Pradies *et al.*, 2015[23]	Lava C.O.S with titanium dioxide powder	Impression – addition silicone Cast – Type IV plaster Scan – Lava Scan ST	Replica method under ×40 magnification	I – mean – 76.33±65.32 mm C – mean – 91.46±72.17 mm
Fitting accuracy of Zirconia single crowns produced via digital and conventional impressions – a clinical comparative study	Rödiger *et al.*, 2017[25]	Heraeus cara TRIOS	Impression – Addition silicone Cast – Type III plaster Scan – D700, 3shape	Replica method under ×35 magnification	I – mean – 87.4±91.2 µm C – D700 – mean – 82.17±75.17 µm
Marginal and Internal Fit of Ceramic Restorations Fabricated Using Digital Scanning and Conventional Impressions: A Clinical Study	Lee *et al.*, 2020[26]	I1 – EZIS PO I2 – i500 I3 – CS3600	Impression – Addition silicone Cast – Type III plaster Scan – E1, 3shape	Replica method under ×60 magnification	I1 – EZIS PO – mean - 49.1±8.8 I2 – i500 - mean - 49.1±7.7 I3 – CS3600 - mean - 56.5±12.7 C – E1 – median - 68.4±8.3

I: Intervention group, C: Comparison group, Q1: First quartile, Q3: Third quartile, SD: Standard deviation, CAD/CAM: Computer aided design-computer aided manufacturing

Table 2: Quality assessment and risk of bias

Criteria	Author and year						
	Syrek *et al.*, 2010[20]	Ahrberg *et al.*, 2015[21]	Boedinghaus *et al.*, 2015[22]	Pradies *et al.*, 2015[23]	Berrendero *et al.*, 2016[24]	Rodiger *et al.*, 2017[25]	Hyeon Lee *et al.*, 2020[26]
Appropriate cross-over design	Low	Low	Low	Low	Low	Low	Low
Randomised treatment order	Low	Low	High	Low	Low	High	High
Carry-over effect	Low	Low	Low	Low	Low	Low	Low
Unbiased data	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Allocation concealment	Low	Low	High	Low	Low	High	High
Blinding	High	Low	High	Unclear	Low	Unclear	Unclear
Incomplete outcome data	Low	Low	Low	Low	Low	Low	Low
Selective outcome reporting	Low	Low	Low	Low	Low	Low	Low
Other bias	Low	Low	Low	Low	Low	Low	Low

DISCUSSION

Full coverage restoration is one of the sought out methods for reinforcing the structural integrity of the endodontically treated tooth. The greater accuracy of the impression obtained will ultimately help in fabricating a crown with a better marginal fit thereby eventually reducing the coronal leakage which is one of the key aspects in determining the success of the endodontic treatment.[5] The trueness and precision are the two parameters that contribute to the accuracy of the impression, a perfect match is said to be an impression with a zero misfit and is therefore considered as an ideal precision. The precision of a method reflects its reproducibility in providing measurements. The deviation in values from misfit of zero indicates poorer precision.[7]

Currently, there is no systematic review to provide clarity toward the superiority or the inferiority of the direct

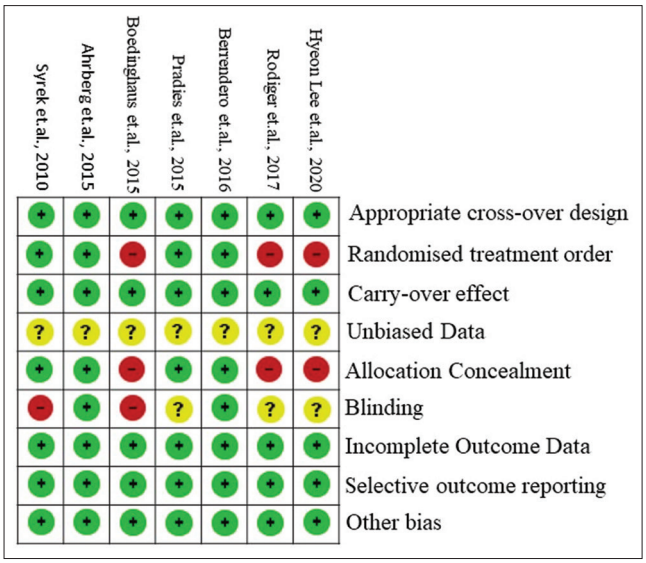

Figure 2: Quality assessment of the studies included in this review

digital impression methods over the indirect digital impression methods for the fabrication of single crowns in terms of dimensional accuracy and marginal fit. This systematic review is aimed at evaluating the dimensional accuracy of digital impressions acquired from intraoral scanners compared with those from laboratory scanners for fabricating crowns by the CAD-CAM method.

The indirect digital impression involves obtaining the digital measurements of the tooth through several steps before scanning, i.e., a conventional impression the preparation (with irreversible hydrocolloids or elastomeric impression materials are widely used for acquiring the negative replica of the prepared tooth)[27] followed by disinfection of the impression, transportation to the laboratories where the cast is fabricated and is scanned using a laboratory scanner. All these procedures involve manual workflow directly influenced by the operator's skill and expertise. The impression materials despite the attempts to optimize their properties undergo dimensional changes to a certain extent due to their inherent factors and environmental factors.[26] The type III and type IV plasters used for making the cast exhibit a certain degree of expansion after setting which could further contribute to the discrepancy.[28] Errors occurring at various steps will ultimately result in a cumulative error in the indirect digital impression. The direct digital workflow, however, does not require a physical cast; instead, the crown is fabricated directly from the digital impression from the intraoral scanner. This process thereby enables the operator to avoid the cumulative errors which could occur during the use of an indirect scanning method.

All the studies included in this review employed a cross-over design where the same preparation was used for the fabrication of all-ceramic crowns by both the modalities and the marginal fit of the resultant crowns was evaluated by replica method using light body elastomeric material examined under magnification. The tooth preparation involved predominantly placement of shoulder or chamfer finish line at the level of the gingival margin or a level below the level of the gingival margin, not exceeding a depth of 1 mm in an attempt to avoid violation of the biologic width. Following the tooth preparation, provisional restoration was provided and the impression procedures were performed at the next appointment. During the second appointment, the impression procedures were carried out in conjunction with the double cord technique for gingival retraction which provides adequate accessibility for better impressions.

In this review, the marginal fit of the crowns was evaluated, as the initial point of the coronal leakage is possible through the margins of the crowns, and the best achievable marginal fit is desired to avoid it. This marginal fit in all of the included studies is evaluated by the replica method[18-26] wherein during the crown fit appointment the intaglio surface of the crown is filled with a low-viscosity silicone material and is placed onto the prepared tooth where it is held under firmly with digital pressure and allowed the material to set to create a film of material representing the internal gap between the prepared tooth and the crown, following that crown with the set material is removed from the prepared tooth and another layer of light body silicone material of different color gradient is placed in the crown. Once the material is set, both the material is carefully removed without distortion and sectioned. The sectioned replicas were examined under magnification and the thickness of the replica film is measured at the margins. The thickness of the replica film corresponds to the gap between the tooth and the crown. Lesser the thickness of the film at the margin better the fit of crowns at the margin.

Quality assessment and risk of bias revealed 4 out of 7 included studies had a low risk of bias (Syrek *et al*., 2010,[20] Ahrberg *et al*., 2015,[21] Pradies *et al*., 2015,[23] Berrendero *et al*., 2015[24]) and the remaining 3 out of 7 included studies had a moderate risk of bias (Boeddinghaus *et al*., 2015,[22] Rodiger *et al*., 2017,[25] Hyeon Lee *et al*., 2020[26]). The direct digital impressions from the intraoral scanners were either better or comparable to the indirect digital impressions across all the studies. The overall quality of evidence obtained from the included studies is moderate.

Over the years, several modifications with newer technologies have been developed for the intraoral scanners to improve their trueness and precision. Further clinical studies evaluating the new and improved intraoral scanner have to be conducted to assess how close are we to achieving the misfit of zero and producing a crown with a better marginal fit.

CONCLUSION

Based on the data obtained, it can be concluded that the CAD-CAM crowns fabricated from direct digital impressions exhibited a better marginal fit than those crowns fabricated by indirect digital impressions which ultimately results in providing a better coronal seal to the endodontically treated teeth.

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Conflicts of interest
There are no conflicts of interest.

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