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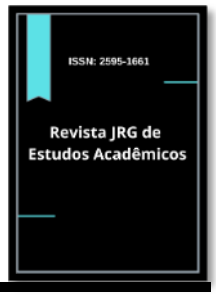

Impact of CAD/CAM systems on the precision of fixed dental prostheses: a systematic literature review

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Abstract

The objective of this study was to evaluate, through a systematic review of the literature, the impact of computer-aided design and computer-aided manufacturing (CAD/CAM) systems on the accuracy of fixed dental prostheses, considering outcomes related to marginal and internal fit. The review was conducted in accordance with the PRISMA 2020 guidelines, with searches performed in the PubMed/MEDLINE and SciELO databases, complemented by manual reference tracking, covering publications from the last ten years. Laboratory and clinical studies that quantitatively assessed the marginal or internal fit of single crowns and fixed partial dentures fabricated using CAD/CAM systems, either in comparison with conventional methods or among different digital workflows, were included. The results demonstrated that, in general, CAD/CAM-fabricated fixed prostheses exhibit fit values considered clinically acceptable, often equivalent to or superior to those obtained with conventional methods, particularly for single-unit restorations. However, significant variability among studies was observed, mainly attributable to differences in the CAD/CAM systems employed, the restorative materials evaluated, digital design parameters, and fit measurement methods. Materials such as zirconia and lithium disilicate showed satisfactory performance, although influenced by specific stages of digital processing. It is concluded that CAD/CAM systems represent a reliable technology for the fabrication of fixed dental prostheses with adequate dimensional accuracy, provided they are applied within well-defined clinical-laboratory protocols. Furthermore, greater methodological standardization in future studies is necessary to strengthen the level of available scientific evidence.

Keywords: CAD/CAM; Fixed dental prosthesis; Marginal fit; Internal fit; Dimensional accuracy.

1. INTRODUCTION

The technological evolution in restorative dentistry has led to significant transformations in diagnostic methods, treatment planning, and the fabrication of fixed dental prostheses, with particular emphasis on the incorporation of computer-aided design and computer-aided manufacturing (CAD/CAM) systems. These systems have been widely adopted due to their promise of greater standardization, a reduction in clinical and laboratory steps, and a potential increase in the quality and predictability of prosthetic rehabilitations. In this context, the dimensional accuracy of fixed prostheses, especially with regard to marginal and internal adaptation, remains one of the main determinants of long-term clinical success (MIYAZAKI et al., 2013; BOEDER et al., 2015). Inadequate marginal adaptation is associated with a range of biological and mechanical complications, including bacterial microleakage, secondary caries, periodontal inflammation, and early restoration failure. Likewise, excessive internal discrepancies may compromise the strength of the restorative material and stress distribution, negatively affecting the longevity of the prosthesis (KARL et al., 2017; CONTREPOIS et al., 2013). Therefore, achieving restorations with high dimensional accuracy constitutes a fundamental requirement for the predictability and durability of prosthetic rehabilitations, justifying the continuous development and evaluation of new technologies applied to prosthodontics.

CAD/CAM systems have introduced digital workflows encompassing intraoral optical impressions, virtual design, and automated manufacturing through subtractive or additive processes. Studies have demonstrated that these digital workflows may offer advantages in terms of reproducibility and dimensional control when compared with conventional methods based on elastomeric impressions and manual laboratory fabrication (ENDO; MEHL, 2015; JODA; BRÄGGER, 2016). However, despite technological advances and the widespread clinical adoption of these systems, the results reported in the literature still show considerable variability, particularly depending on the type of CAD/CAM system used, the restorative material selected, the design parameters applied, and the methods employed to assess prosthetic adaptation. Recent systematic reviews have sought to compare the precision of fixed prostheses fabricated using CAD/CAM systems with that of conventionally manufactured restorations, evaluating outcomes such as marginal adaptation, internal adaptation, and the accuracy of digital impressions. Although some of these studies indicate equivalent or superior performance of digital systems, divergences persist regarding the clinical magnitude of these differences, as well as the influence of methodological factors such as study design, prosthesis extension, and evaluation techniques (AHLHOLM et al., 2018; RODRIGUES et al., 2021). This heterogeneity highlights the lack of definitive consensus in the literature and reinforces the need for a critical, up-to-date, and methodologically rigorous synthesis of the available evidence.

In light of this context, the aim of the present systematic literature review was to comprehensively and systematically evaluate the impact of CAD/CAM systems on the precision of fixed dental prostheses, considering outcomes related to marginal and internal adaptation. The synthesis of scientific evidence published in recent years seeks to clarify the advantages and limitations of these systems, thereby supporting evidence-based clinical decision-making and the continuous improvement of rehabilitative protocols in prosthodontics.

2. METHODOLOGY

This study consisted of a systematic review of the literature, planned and conducted in accordance with the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020), with the objective of evaluating the impact of computer-aided design and computer-aided manufacturing (CAD/CAM) systems on the accuracy of fixed dental prostheses, considering outcomes related to marginal and internal fit. The research question guiding the study was: what is the impact of CAD/CAM systems on the accuracy of fixed dental prostheses when compared with conventional fabrication methods? This question was structured according to the PICOS framework, in which the population comprised fixed dental prostheses, including single crowns and fixed partial dentures, tooth- or implant-supported; the intervention corresponded to fabrication using CAD/CAM systems, involving intraoral or extraoral scanning, digital design, and automated manufacturing through subtractive processes or additive manufacturing; the comparison included conventional impression and prosthetic fabrication methods or comparisons among different digital workflows; the outcomes encompassed measures of prosthetic accuracy, assessed through marginal and internal fit, frequently expressed in micrometers; and eligible studies included laboratory and clinical investigations that presented quantitative measurements of these outcomes.

The bibliographic search was conducted in the PubMed/MEDLINE and SciELO databases, complemented by manual screening of the reference lists of eligible studies, considering publications from the last ten years. Full-text scientific articles published in indexed journals that objectively evaluated the marginal or internal fit of fixed dental prostheses fabricated using CAD/CAM systems, with comparisons to conventional methods or among different digital workflows, were included. Case reports, editorials, letters to the editor, studies without quantitative measurements of prosthetic fit, investigations focused exclusively on removable or complete dentures, and duplicate publications were excluded.

Study selection was performed in two stages, beginning with the screening of titles and abstracts, followed by full-text reading of potentially eligible articles to confirm inclusion criteria. The study selection flow, including identification, duplicate removal, screening, and eligibility, was organized in accordance with PRISMA 2020 guidelines and will be presented using a flow diagram. Data from the included studies were extracted in a standardized manner, including author and year of publication, study design, type of fixed dental prosthesis evaluated, CAD/CAM system and workflow employed, restorative material used, method of prosthetic fit measurement, and marginal and internal fit values.

Methodological quality assessment considered the design of each included study, analyzing aspects such as standardization of tooth preparations, methodological clarity, measurement methods employed, evaluator calibration, and reproducibility of measurements in laboratory studies, as well as control of variables and adequate description of procedures in clinical studies. Due to the heterogeneity observed among the studies, related to differences in CAD/CAM systems, restorative materials, and measurement methods, the results were synthesized through a qualitative descriptive analysis, organized comparatively, allowing the identification of trends regarding the performance of CAD/CAM systems in relation to conventional methods. As this study was based exclusively on secondary data derived from the scientific literature, submission to a Research Ethics Committee was not required.

3. RESULTS AND DISCUSSION

The analysis of the studies included in this systematic review demonstrated that CAD/CAM systems exert a relevant influence on the accuracy of fixed dental prostheses, particularly with respect to marginal and internal fit. Overall, the analyzed studies reported that prostheses fabricated using digital workflows exhibited fit values considered clinically acceptable, frequently equivalent to or superior to those obtained with conventional impression and prosthetic fabrication methods. These findings were mainly observed in single crowns and short-span fixed partial dentures.

However, a wide variability in results was identified among the included studies, associated with differences in the CAD/CAM systems used, the restorative materials evaluated, and the digital design parameters adopted. Studies investigating polycrystalline ceramics, such as zirconia, reported adequate marginal fit values, although these were sensitive to milling and sintering stages. In contrast, restorations fabricated from glass-ceramic materials, such as lithium disilicate, demonstrated more consistent outcomes regarding both marginal and internal fit.

With respect to impression acquisition, most studies indicated a favorable trend toward digital impressions compared with conventional impressions, particularly in terms of reproducibility and dimensional control in single-unit restorations. Nevertheless, for long-span fixed partial dentures, some studies reported similar results between digital and conventional workflows, suggesting the influence of additional factors, such as the extent of the rehabilitation and operator experience.

Additionally, the included studies highlighted that parameters defined during the digital design stage, such as cement space and margin definition, had a direct impact on internal and marginal fit outcomes. Studies that adopted standardized protocols for these parameters showed greater consistency in their results, whereas those with substantial methodological variation demonstrated significant discrepancies.

3.1 IMPACT OF CAD/CAM SYSTEMS ON MARGINAL AND INTERNAL FIT

The findings of this review indicate that CAD/CAM systems are capable of producing fixed dental prostheses with dimensional accuracy compatible with current clinical requirements. The marginal and internal fit reported in the analyzed studies reinforces that digital workflows represent a well-established alternative to conventional methods, particularly in clinical situations of lower complexity. These results support the growing adoption of CAD/CAM systems in contemporary clinical practice, driven by the predictability and standardization inherent to the digital environment.

3.2 INFLUENCE OF RESTORATIVE MATERIAL ON PROSTHETIC ACCURACY

The analysis of the studies revealed that the restorative material plays a decisive role in the final accuracy of CAD/CAM-fabricated prostheses. Polycrystalline materials, such as zirconia, demonstrated adequate marginal fit; however, they were susceptible to dimensional changes resulting from milling and sintering stages. In contrast, glass-ceramic materials, such as lithium disilicate, showed greater dimensional predictability, reflected in more homogeneous marginal and internal fit outcomes. These findings indicate that material selection should be carefully considered when evaluating the performance of CAD/CAM systems.

3.3 DIGITAL IMPRESSION VERSUS CONVENTIONAL IMPRESSION

The comparison between digital and conventional impression techniques highlighted advantages of intraoral scanning systems, particularly regarding reproducibility and reduction of cumulative distortions. The elimination of intermediate steps inherent to conventional impressions appears to contribute to improved dimensional control, especially for single-unit restorations. However, in long-span prostheses, less consistent results suggest that technical and operational limitations may still influence the performance of digital workflows, reinforcing the need for case-by-case evaluation.

3.4 ROLE OF DIGITAL DESIGN PARAMETERS AND CEMENT SPACE

Parameters defined during the digital planning stage proved to be critical for achieving precise outcomes. Standardization of cement space and accurate definition of prosthetic margins were associated with improved internal and marginal fit results. These findings demonstrate that the performance of CAD/CAM systems depends not only on the technology itself but also on the clinician's technical expertise and appropriate software configuration, underscoring the importance of clinical and laboratory training.

3.5 METHODOLOGICAL LIMITATIONS AND CLINICAL IMPLICATIONS

Despite the favorable results, the methodological heterogeneity observed among the analyzed studies limits direct comparison of findings and absolute generalization of the results. Differences in fit measurement methods, as well as variations in experimental designs, hinder data standardization. Therefore, although CAD/CAM systems demonstrate clinically acceptable performance, the results should be interpreted with caution. From a clinical perspective, the findings reinforce the need for well-defined protocols and individualized rehabilitative planning, considering material selection, prosthesis span, and mastery of the digital workflow.

4. CONCLUSION

Based on the systematic analysis of the available literature, it can be concluded that CAD/CAM systems represent a reliable and clinically viable technology for the fabrication of fixed dental prostheses with adequate dimensional accuracy, particularly with respect to marginal and internal fit. Overall, digital workflows demonstrated performance equivalent to or superior to conventional methods, reinforcing their consolidation in contemporary clinical practice.

However, the benefits associated with CAD/CAM systems do not rely exclusively on the digital technology itself, but are directly related to the careful selection of restorative materials, the appropriate definition of digital design parameters, and the standardization of clinical–laboratory protocols. The methodological variability observed in the literature indicates that prosthetic accuracy results from the interaction among the system, the material, and technical execution, requiring thorough mastery of the digital workflow by the clinician.

Additionally, the limitations identified in the analyzed studies, particularly the heterogeneity of measurement methods and experimental designs, highlight the need for greater methodological standardization in future research. Well-designed clinical studies and laboratory investigations using uniform protocols are essential to strengthen the level of scientific evidence and to allow more robust comparisons among different CAD/CAM systems.

Thus, although CAD/CAM systems present consistent and clinically acceptable results, their application should be grounded in up-to-date scientific evidence and adapted to the specific characteristics of each clinical case. Continuous technological advancement, combined with professional training and the development of evidence-based protocols, is expected to further enhance the predictability and longevity of prosthetic rehabilitations within the field of Prosthodontics.

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