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Original Article

Accuracy of digital impressions captured by an intraoral scanner in a partially edentulous mandible

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Abstract *Background/purpose:* The effectiveness of intraoral scanners in accurately recording partially edentulous mandibles is still under scrutiny. This study aimed to assess the accuracy of digital impressions obtained using an intraoral scanner in a partially edentulous mandibular arch.
Materials and methods: A partially edentulous typodont model with missing five teeth was digitally scanned using a calibrated desktop scanner to create a reference model. The scan was saved as a standard tessellation language (STL) file and used as the control dataset. The same typodont model was then scanned 20 times using an intraoral scanner (IOS), with each digital impression exported in STL format. All datasets were analyzed using a best-fit registration algorithm in specialized software to compare the IOS scans against the reference model.
Results: Three-dimensional positional deviations were analyzed, which quantified the average deviation between the scanned data and the control model, indicating accuracy. Tooth 37 (lower left second molar) had the lowest mean deviation (49.75 ± 10.05 μm), while tooth 45 (lower right second premolar) showed the highest (54.35 ± 7.23 μm). Moderate deviations

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were noted in teeth 34 (lower left first premolar) and 45 (lower right second premolar), with tooth 37 (lower left second molar) demonstrating the greatest variability. Statistical analysis of the datasets for teeth 34, 37, and 45 revealed no significant differences among them ($p > 0.05$).
Conclusion: The findings of this study indicate that the intraoral scanner evaluated is capable of generating digital impressions with clinically acceptable accuracy in partially edentulous mandibular arches.

Introduction

The advent of intraoral scanners (IOSs) has significantly transformed modern dental practices, particularly in diagnostics, treatment planning, and patient care.[1,2] These devices eliminate the need for traditional polyvinyl siloxane (PVS) impressions by capturing multiple images within the oral cavity and stitching them into a detailed three-dimensional (3D) model.[3,4] This advancement not only enhances patient comfort but also improves the accuracy and efficiency of dental procedures. With the ability to generate high-resolution digital representations of tooth preparations in real-time, clinicians can better assess and refine fixed partial denture (FPD) designs.[4] As digital dentistry continues to evolve, the adoption of IOSs is expected to expand across all dental specialties, streamlining workflows and optimizing clinical outcomes.

Desktop scanners have long been regarded as the gold standard in digital scanning technology due to their ability to capture highly precise 3D models of dental impressions and restorations.[5,6] Using advanced light and laser technology combined with a rotating platform, desktop scanners provide an unparalleled level of accuracy by eliminating external interferences that may compromise the scanning process. Despite these advantages, their high cost, space requirements, and need for specialized expertise have limited their widespread use in general dental practices. Consequently, IOSs were developed to replicate the capabilities of desktop scanners while offering greater accessibility and convenience. Initially introduced for single-crown digital impressions, IOS technology has since demonstrated significant potential in fabricating both short- and long-span FPDs, making it an invaluable tool in restorative and prosthetic dentistry.[7–9]

The conventional crown and bridge fabrication process remains a widely accepted treatment option due to anatomical and financial considerations, despite advancements in implant dentistry. Traditional workflows involve multiple steps, including tooth preparation, gingival retraction, PVS impression-taking, and model fabrication, often requiring the assistance of another clinician. The manual nature of this process can lead to errors that necessitate repeated impressions, increasing chairside time and patient discomfort. Accurate impressions for removable partial dentures are also essential, particularly for precisely capturing the positions of abutment teeth, where metal framework components such as clasps, rest seats, and guide planes will be placed. While research suggests that digital impressions can achieve similar levels of accuracy in fixed prosthodontics, challenges remain regarding the precision of IOSs in capturing edentulous or partially edentulous arches.[10,11]

When evaluating the use of intraoral scanners (IOS) for removable prostheses, such as complete dentures (CD) and removable partial dentures (RPD), only a limited number of scanners on the market possess the technological capability to accurately capture critical anatomic landmarks essential for retention and support. Despite significant advancements in IOS technology, the literature continues to present conflicting reports regarding the accuracy of various scanners, particularly when challenged with full-arch or complete denture scanning.[12,13] Several factors influence the precision of digital impressions, including scanner resolution, software algorithms, and surface reflectivity. Given these limitations, clinicians must thoroughly evaluate an IOS's performance before integrating it into the workflow for complete and partial denture fabrication.

The aim of this research was to evaluate the accuracy of digital impressions generated by the IOS and its associated software for partially edentulous typodont models.

Materials and methods

For the reference (control) model, a digital impression of a partially edentulous typodont model, missing five teeth (left second premolar and first molar, as well as the right molars), was acquired using a calibrated desktop scanner (E3, 3Shape, Copenhagen, Denmark). The resulting scan was saved as a standard tessellation language (STL) file, which served as the reference dataset.

Subsequently, the same partially edentulous typodont model was scanned using an intraoral scanner (IOS) (Planmeca Emerald S, D4D Technologies LLC, Richardson, TX, USA) to obtain 20 independent digital scans. Each scan was then exported in STL file format for further analysis.

The datasets obtained from the reference model (single STL file) and the intraoral scanner (20 STL files) were compared using a best-fit registration algorithm within a specialized software program (GOM Inspect Professional 2017, Braunschweig, Germany). This study focused on evaluating the positional accuracy of three abutment teeth, as their precise positioning is critical for ensuring the proper fit of metal frameworks in removable partial dentures (Figs. 1 and 2). Therefore, the root mean square (RMS) error and angular deviation values were computed for three abutment teeth. The RMS error quantifies the absolute mean distances between corresponding points, providing a measure of the similarity and discrepancy between the compared surfaces. Lower RMS values indicate greater similarity, while higher values denote increased divergence.

The study data were processed and analyzed using the R programming language (https://cran.r-project.org/). To assess the normality of numerical data, both analytical methods (such as the Shapiro—Wilk normality test) and graphical techniques (including histograms and Q—Q plots) were employed. Based on the normality assessment, numerical data were summarized using either the mean and standard deviation for normally distributed data or the median and interquartile range for non-normally distributed data. The coefficient of variation (CV) was calculated within each tooth to quantify variability across repeated scans of the same location. These CV values were then categorized to evaluate the degree of concordance between repeated measurements. Briefly, the CV is expressed as a decimal or percentage and helps compare variability between datasets with different units or scales. The interpretation of CV values in notation is:

1) $CV < 0.10$ = Low variation: The data points are close to the mean, indicating stability and consistency.
2) $0.10 < CV < 0.20$ = Moderate variation: Some level of dispersion exists, but the data is still relatively stable.
3) $0.20 < CV < 0.30$ = High variation: Greater spread in the data, suggesting inconsistency.
4) $CV > 0.30$ = Very high variation: Significant fluctuations in the data, indicating a lack of uniformity.

A lower CV indicates more consistency, while a higher CV suggests greater variability.

Additionally, Pearson's correlation coefficient was used to analyze the relationship between the examined teeth. A *P*-value of less than 0.05 was considered indicative of statistical significance across all analyses.

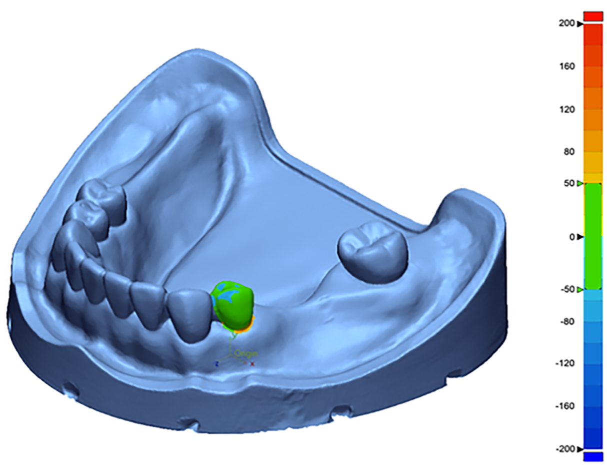

Figure 1 Superimposed digital scan images from the desktop scanner and intraoral scanner illustrating the deviation observed at the mandibular left first premolar.

Results

A reference scan was acquired using a desktop scanner and served as the control, while a total of 20 scans were obtained using a single intraoral scanner, generating 20 STL files.

The deviations between the reference scan and the 20 intraoral scans were assessed based on three-dimensional

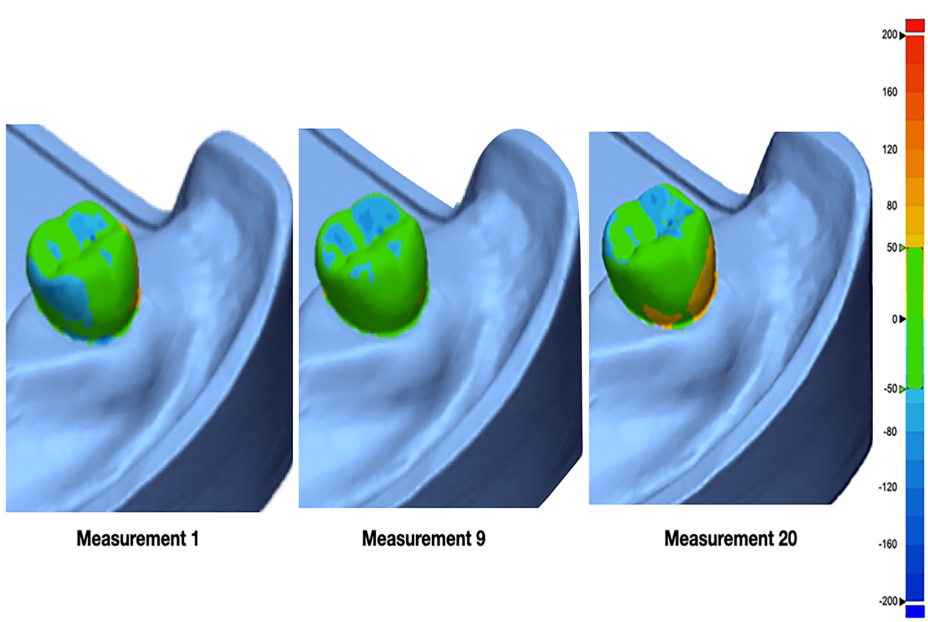

Figure 2 Comparison of three superimposed digital scans from desktop and intraoral scanners, highlighting deviations at the mandibular left second molar.

(3D) positional discrepancies using the root mean square (RMS) statistical method. This analysis quantified the average deviation between the predicted model values and the actual reference values, representing accuracy. As shown in Table 1, the lowest mean deviation was recorded for tooth 37 (49.75 ± 10.05 μm), while the highest mean deviation was observed for tooth 45 at 54.35 ± 7.23 μm. Moderate variations were noted in tooth 34 and tooth 45, whereas tooth 37 exhibited the highest variation (Table 2).

Correlations among the datasets for the three examined teeth (34, 37, and 45) were also analyzed, revealing no statistically significant differences among them ($P > 0.05$).

Discussion

The findings of this study demonstrate that intraoral scanners (IOSs), specifically the Planmeca Emerald S, are capable of producing clinically acceptable digital impressions in partially edentulous mandibular arches. Mean deviations ranging from 49.75 μm to 54.35 μm across three abutment teeth suggest that IOSs meet the accuracy demands required for prosthodontic procedures. These values fall well within the threshold considered acceptable for fixed and removable prosthodontic applications, supporting a growing consensus in the literature that IOSs are a viable alternative to conventional impression materials, particularly when considering their advantages in efficiency, patient comfort, and workflow integration.[14,15]

Analysis of individual abutment teeth revealed notable spatial variability, with tooth 37 located in the distal posterior region, exhibiting the greatest variation (CV = 0.202). This finding is in agreement with previous reports indicating decreased scanning accuracy in posterior regions of the oral cavity,[16] which can be attributed to a range of anatomical and technical challenges. Limited intraoral visibility, greater soft tissue mobility, and suboptimal scanner angulation in posterior areas complicate the acquisition of accurate surface data. Conversely, teeth located in anterior or premolar regions, such as teeth 34 and 45 in this study, demonstrated more consistent results (CV < 0.20), corroborating findings by Guth et al.,[17] and Zarauz et al.,[18] who emphasized higher reproducibility of IOSs in these regions.

Interestingly, the absence of statistically significant correlations among the positional deviations of the three abutment teeth ($p > 0.05$) suggests that impression inaccuracies are more likely driven by localized anatomical and scanning variables rather than consistent flaws in the scanning system itself. This observation aligns with the findings of Ender et al.,[19] and Schmidt et al.,[20] who reported similar patterns of variability in full-arch digital impressions.

Despite ongoing improvements, limitations remain in IOS performance, particularly in capturing edentulous areas and mobile soft tissues. These regions are prone to image stitching errors and software-based interpolation, which may compromise trueness.[21] This limitation is especially relevant in the context of removable partial denture (RPD) design, where accurate localization of rest seats, guide planes, and clasp assemblies is critical. Therefore, while digital impressions hold significant promise, clinicians must exercise caution when digitizing highly variable or edentulous soft tissue zones.

It is also important to acknowledge that while desktop scanners continue to serve as the gold standard for digital accuracy due to their higher resolution and greater stability,[16] IOSs offer distinct clinical advantages. Their portability, real-time feedback, reduced need for retakes, and improved patient experience enhance their practical utility in daily practice. As demonstrated in this study, deviations under 60 μm fall within acceptable limits for most clinical scenarios, aligning with benchmarks proposed by Ender and Mehl.[22] Taken together, these results support the thoughtful integration of IOS technology into contemporary prosthodontic workflows, while highlighting the importance of anatomical awareness and case selection for optimal outcomes.

This study offers valuable insight into the precision of digital impressions produced by intraoral scanners (IOSs) in a controlled in vitro environment, demonstrating clinically acceptable accuracy in partially edentulous mandibular arches. The findings support the growing role of IOSs in prosthodontics, particularly for applications involving abutment teeth in anterior and premolar regions. However, the controlled nature of the experimental setting does not fully replicate the clinical complexities encountered in vivo. To enhance the generalizability of these results, future research should include intraoral studies involving patients with varying degrees of edentulism, diverse anatomical conditions, and dynamic soft tissue behavior.

Table 1 Overall deviation values (mean ± standard deviation in microns) for each tooth.

Region	Mean ± SD (microns)	CV (coefficient of variation)	Variation
Tooth 34 (Left 1st premolar)	52.55 ± 7.94	0.151	Moderate
Tooth 37 (Left 2nd molar)	49.75 ± 10.05	0.202	High
Tooth 45 (Right 2nd premolar)	54.35 ± 7.23	0.133	Moderate

Table 2 Correlations among three teeth, indicating no statistically significant differences ($P > 0.05$).

Region	Tooth 37	Tooth 34	Tooth 45
Tooth 34 (Left 1st premolar)	1.000	0.3015	0.2783
Tooth 37 (Left 2nd molar)	0.3015	1.000	−0.1326
Tooth 45 (Right 2nd premolar)	0.2783	−0.1326	1.000

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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