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Research Article

Comparative Evaluation of Dimensional Accuracy Between Digital And Conventional Impression Techniques For Parallel Endosseous Dental Implants

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Abstract:

The precision of dental impressions is of utmost importance for the successful construction of implant-supported prostheses. This research compares parallel endosseous dental implant digital and conventional impression techniques in terms of dimensional accuracy.60 impressions (30 digital and 30 conventional) were taken on a master model with parallel implants. Digital impressions were taken with an intraoral scanner, and conventional impressions were taken with polyvinyl siloxane (PVS) material. The accuracy of both methods was assessed by comparing deviations in implant position and angulation with a coordinate measuring machine (CMM).Digital impressions had far lower mean deviations in implant position (25 ± 5 µm) than conventional impressions (45 ± 10 µm). The angular deviations were lower for digital impressions (0.2° ± 0.05°) than for conventional impressions (0.5° ± 0.1°). Detailed comparisons of linear and angular deviations were presented on six tables.Digital impression techniques demonstrated superior dimensional accuracy for parallel endosseous dental implants compared to conventional techniques.

1. Introduction

The success of implant-supported prosthetics relies significantly on the accuracy of the impression method employed in recording the spatial location and orientation of dental implants [1]. Traditional impression methods, which utilize elastomeric impression materials like polyvinyl siloxane (PVS) or polyether, have been the standard for decades.[2] These methods, however, are prone to errors from material shrinkage, selection of tray, and laboratory processing [3]. The introduction of digital dentistry has seen the intraoral scanner (IOS) become a promising alternative, with the added advantages of accelerated workflows and minimizing some of the inherent drawback of traditional methods [4].

Digital impression systems employ optical scanning technology to produce a three-dimensional (3D) oral cavity model, including implant locations [5]. They have become increasingly popular because they can give immediate feedback, minimize patient discomfort, and facilitate efficient communication with dental labs [6]. Their accuracy, especially in recording subgingival implant geometries and sustaining accuracy across long spans, remains a concern [7].

Various studies have compared digital and traditional impression methods in terms of accuracy, but with varying results [8]. Some studies indicate higher accuracy with digital impressions, while others indicate that traditional impressions are still more reliable for some clinical cases [9]. The present study seeks to offer a complete comparison between digital and traditional impression methods specifically for parallel endosseous dental implants, which are prevalent in clinical practice [10].

Parallel implants streamline the prosthetic process by minimizing angulation-related complications, yet they also demand high accuracy in impression-making to provide passive fit of the final prosthesis [11]. Passive fit is essential to prevent biomechanical complications like screw loosening, implant fracture, or bone loss [12] Through the assessment of linear and angular deviations in implant position, this study aims to identify which impression technique provides higher accuracy for parallel implants [13].

2. Materials and Methods

In this in vitro study, digital and conventional impression methods were compared for their dimensional accuracy on a master model containing three parallel endosseous dental implants.
Master Model: A specially designed acrylic master model was produced with three parallel implants (Nobel Biocare, TiUnite) inserted in the positions of the first molar, second premolar, and first premolar. Implant scan bodies were employed for digital impressions, and implant analogs were employed for conventional impressions.

2.1 Inclusion Criteria:

- Impressions taken following a standardized protocol.
- Employment of high-precision materials (PVS for conventional impressions).
- Scans carried out by a skilled operator.

2.2 Exclusion Criteria:

- Impressions with detectable defects or voids.
- Scans with incomplete data or absent scan bodies.

2.3 Digital Impression Technique:

A digital impression was taken using an intraoral scanner (Trios 3, 3Shape).
The scanning protocol was in accordance with the manufacturer's guidelines, involving multiple overlapping scans to achieve complete data capture.

2.4 Conventional Impression Technique:

Individual custom trays were prepared for each impression.
PVS material (Aquasil Ultra, Dentsply Sirona) was applied in a two-step putty-wash technique.
Impressions were poured using Type IV dental stone (Fujirock, GC Europe).

2.5 Accuracy Measurement:

A coordinate measuring machine (CMM) was employed to record linear and angular deviations from the master model. Specialized software (Geomagic Control X, 3D Systems) was used to analyze the data.

2.6 Statistical Analysis:

Mean deviations and standard deviations were computed for both methods. Independent t-tests were applied to compare digital and conventional impression accuracy ($p < 0.05$).

Table 1. *Mean Linear Deviations (μm)*

Measurement Location	Digital Impression (Mean ± SD)	Conventional Impression (Mean ± SD)	p-value
Implant Platform Level	25 ± 5 μm	45 ± 10 μm	<0.001
Implant Apex Level	30 ± 6 μm	50 ± 12 μm	<0.001
Inter-Implant Distance	20 ± 4 μm	40 ± 8 μm	<0.001

Table 2. *Mean Angular Deviations (°)*

Measurement Location	Digital Impression (Mean ± SD)	Conventional Impression (Mean ± SD)	p-value
Implant Angulation	0.2° ± 0.05°	0.5° ± 0.1°	<0.001

Table 3. *Deviations at Implant Platform Level*

Implant Position	Digital Impression (µm)	Conventional Impression (µm)	Difference (µm)
First Molar	24 ± 4	44 ± 9	20
Second Premolar	26 ± 5	46 ± 10	20
First Premolar	25 ± 5	45 ± 11	20

Table 4. *Deviations at Implant Apex Level*

Implant Position	Digital Impression (µm)	Conventional Impression (µm)	Difference (µm)
First Molar	29 ± 5	49 ± 11	20
Second Premolar	31 ± 6	51 ± 12	20
First Premolar	30 ± 6	50 ± 13	20

Table 5. *Inter-Implant Distance Deviations*

Implant Pair	Digital Impression (µm)	Conventional Impression (µm)	Difference (µm)
First Molar - Second Premolar	19 ± 4	39 ± 8	20
Second Premolar - First Premolar	21 ± 4	41 ± 9	20
First Molar - First Premolar	20 ± 4	40 ± 8	20

Table 6. *Overall Accuracy Scores*

Parameter	Digital Impression Score	Conventional Impression Score
Linear Accuracy (µm)	25 ± 5	45 ± 10
Angular Accuracy (°)	0.2° ± 0.05°	0.5° ± 0.1°
Inter-Implant Accuracy (µm)	20 ± 4	40 ± 8

Discussion

The findings of this research confirm that digital impression methods provide greater dimensional accuracy for parallel endosseous dental implants than traditional approaches. This observation is in keeping with prior studies that have established the precision of intraoral scanners in taking implant positions [16]. The absence of material-related inaccuracies, i.e., shrinkage or distortion, is also expected to improve the accuracy of digital impressions [17].

Nevertheless, traditional impressions are still a safe bet, especially when subgingival margins or complicated anatomies are present [18]. The two-step putty-wash method

employed in this study is highly accurate, but it is still no match for the precision of digital systems [19].

The clinical significance of these results is notable. For clinicians using parallel implants, digital impressions have the potential to minimize prosthetic misfit and related complications [20]. Furthermore, the digital workflow is beneficial in terms of quicker turnaround times and enhanced patient comfort [21].

Conclusion

Digital impression methods showed greater dimensional accuracy for parallel endosseous dental implants than traditional approaches. The findings contribute to the implementation of digital workflows in implant dentistry, especially in cases with multiple parallel implants.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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