



Photogrammetry in Dental Implant Patients: Accuracy, Clinical Workflow, and Prosthetic Outcomes

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Abstract

Objective:

To evaluate the clinical application of photogrammetry in dental implant patients, with emphasis on accuracy, workflow efficiency, and prosthetic outcomes when compared with conventional and intraoral scanning impression techniques.



Conventional dental implant impression:



Intraoral scanning impression :





Methods:

The contemporary dental literature was conducted, focusing on studies that assessed photogrammetry systems used in implant dentistry. Parameters analyzed included accuracy of implant position transfer, time efficiency, patient comfort, and prosthetic fit in single and multiple implant cases.



Precision ICam (by Imetric4D)

Both ICam (by Imetric4D) and PIC Dental are advanced, high-precision, photo-based, 3D dental-implant-positioning, and 3D digital-implant-positions, or "photogrammetry," tools, specifically designed for full-arch (All-on-4/X) restorations, designed to provide a "passive fit" for the final prosthetics.



Results:

Photogrammetry demonstrated superior accuracy in capturing three-dimensional implant positions, particularly in full-arch and multi-implant restorations. Compared to conventional impressions

and intraoral scanners, photogrammetry reduced distortion, improved passive fit of implant-supported prostheses, and shortened clinical and laboratory workflows. Patient comfort and clinician predictability were also improved.

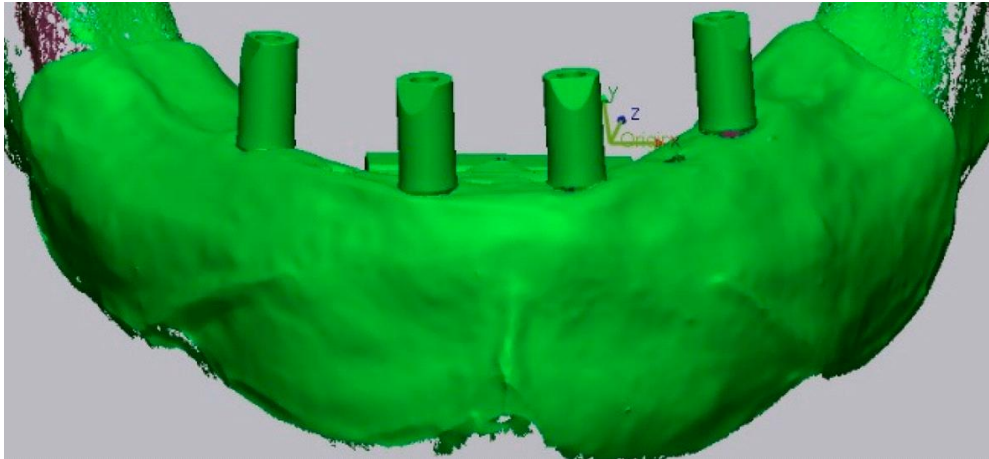


Conclusion:

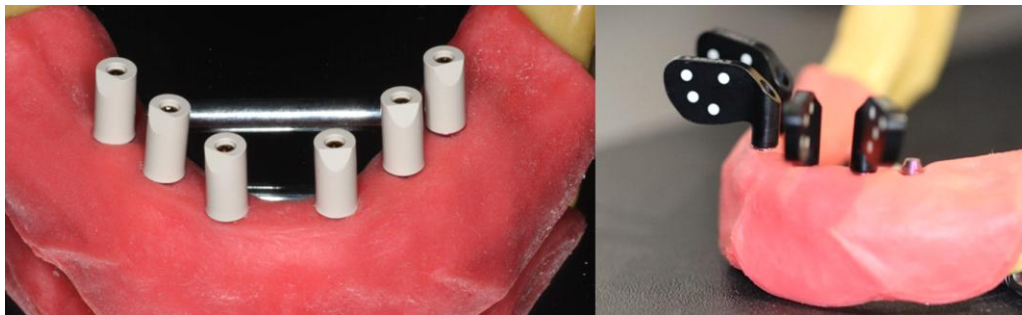
Photogrammetry represents a reliable and highly accurate digital impression method for implant patients, especially in complex cases. Its integration into digital workflows enhances prosthetic precision, reduces chair time, and supports long-term implant success, and for full-arch (All-on-4/X) restorations.

Three-Dimensional Spatial Accuracy of Implant Position Transfer

Accurate transfer of the **three-dimensional (3D) spatial position of dental implants**—including linear (X, Y, Z axes) and angular relationships—is essential for achieving passive fit and biomechanical stability in implant-supported prostheses. Photogrammetry has consistently demonstrated superior performance in accurately capturing implant positions compared with conventional impression techniques and intraoral scanning (IOS), particularly in multi-implant and full-arch cases.



Photogrammetry systems utilize multiple calibrated images of rigid implant-mounted scan bodies to calculate exact spatial coordinates through triangulation. This method avoids surface stitching errors and minimizes distortions related to soft tissue movement or limited anatomical landmarks, which commonly affect conventional and IOS techniques.



Linear and Angular Deviation in Implant Photogrammetry

The enhanced accuracy of photogrammetry is reflected in significantly reduced **linear deviation (μm)** and **angular deviation (degrees)** between planned and recorded implant positions. These parameters are critical, as even small inaccuracies can accumulate across multiple implants, leading to prosthetic misfit and mechanical complications.

I. Introduction

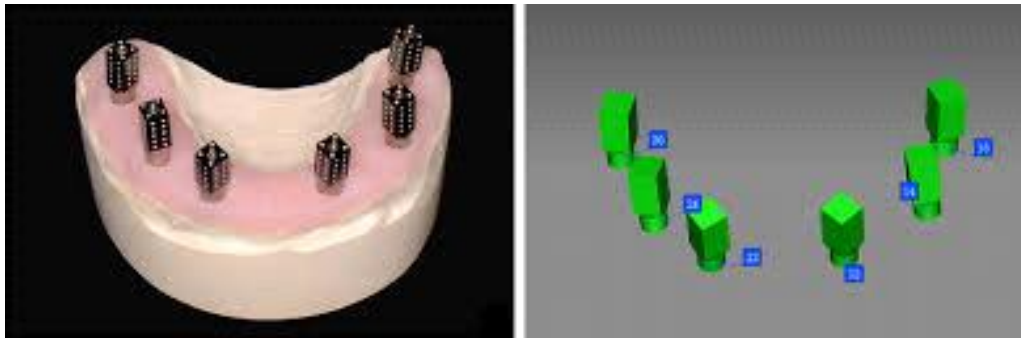
Accurate transfer of implant position is a critical factor in implant-supported prosthodontics. Errors in impression techniques can result in misfit, mechanical complications, and biological issues such as peri-implant bone loss. Traditional impression methods, while widely used, are

susceptible to material distortion and technique sensitivity.

With the advancement of digital dentistry, photogrammetry has emerged as a precise alternative for recording implant positions. Unlike intraoral scanners that capture surface data, photogrammetry relies on calibrated photographic images to calculate exact spatial relationships between implants.

Background and Rationale

Photogrammetry is a three-dimensional measurement technique based on the triangulation of multiple high-resolution images. In implant dentistry, specially designed scan bodies or markers are attached to implants, and a series of photographs are taken from different angles. Software algorithms then reconstruct the precise implant positions in three-dimensional space.



This technology was initially adopted in aerospace and engineering fields and later adapted for dental implant applications, particularly full-arch (All-on-4/X) restorations where accuracy is paramount.

II. Materials and Methods

Study Design

Inclusion Criteria

- Studies evaluating photogrammetry in implant dentistry
- Clinical or in vitro studies involving single or multiple implants
- Comparisons with conventional impressions or intraoral scanners

Evaluated Parameters

- Accuracy of implant position transfer

- Passive fit of implant-supported prostheses
- Clinical time efficiency
- Patient comfort
- Prosthetic complications

Clinical Workflow of Photogrammetry in Implant Patients

- Placement of photogrammetry scan bodies on implants
- Capture of calibrated photographic images using a dedicated camera system
- Software-based three-dimensional reconstruction of implant positions
- Integration with CAD/CAM software for prosthetic design
- Fabrication of implant-supported restorations

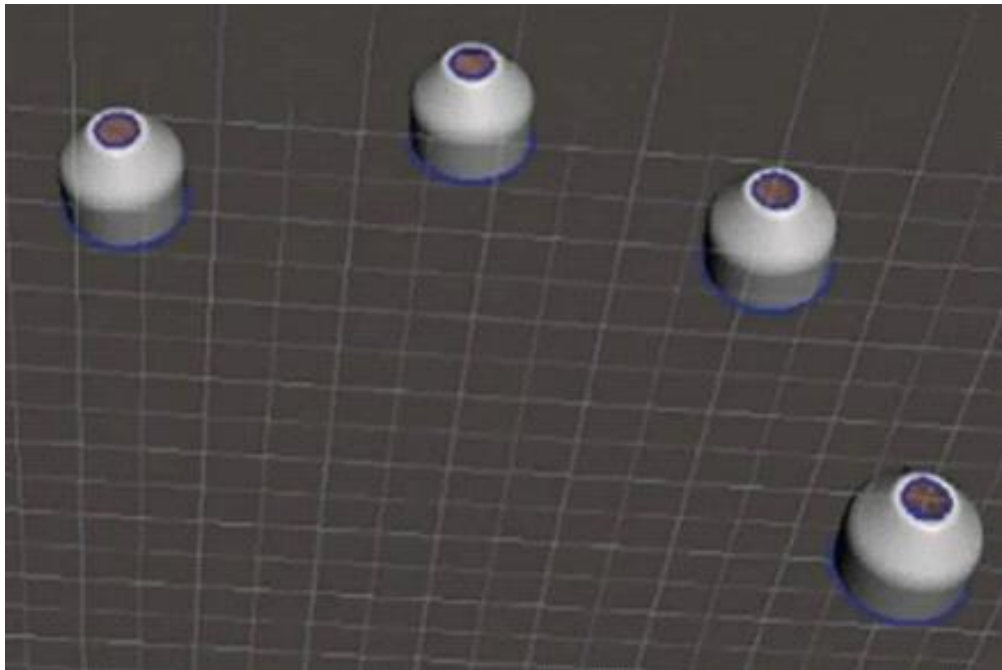


This workflow eliminates impression materials and reduces the need for repeated adjustments.

III. Results and Findings

Accuracy

Photogrammetry consistently demonstrated higher accuracy than conventional impressions and intraoral scanning, especially in cases involving more than four implants.



Prosthetic Fit

Studies reported improved passive fit of full-arch frameworks, reducing mechanical stress on implants and prosthetic screws.



Efficiency

Clinical chair time was reduced due to faster data acquisition and fewer remakes or adjustments.

Patient Experience

Patients reported greater comfort due to the non-invasive nature of image-based impressions.

Table 1. Comparison of 3D Accuracy Values Among Impression Techniques for Dental Implants

Impression Technique	Linear Deviation (μm)	Angular Deviation ($^\circ$)	Accuracy in Full-Arch Cases	Clinical Implications
Photogrammetry	5–20 μm	0.1–0.3 $^\circ$	High	Excellent passive fit, reduced



				mechanical stress, ideal for full-arch and immediate-load restorations
Intraoral Scanner (IOS)	20–80 μm	0.3–1.2°	Moderate to Low	Acceptable for single or short-span implants; accuracy decreases with increased implant number
Conventional Impression	50–150 μm	0.5–2.0°	Low	Higher risk of distortion; increased need for verification jigs and prosthetic adjustments

Values represent approximate ranges reported in contemporary *in vitro* and clinical studies.

Comparison with Other Digital Impression Techniques

While intraoral scanners provide acceptable results for single or short-span implant restorations, their accuracy decreases in edentulous arches due to the absence of fixed anatomical landmarks. Photogrammetry overcomes this limitation by relying solely on implant-based reference points, making it especially advantageous for:

- Full-arch implant restorations
- Immediate-loading protocols

- Cases requiring high precision and predictability

Clinical Relevance

The ability of photogrammetry to accurately reproduce the 3D spatial position of implants enhances clinical confidence and prosthetic predictability. This technology streamlines the digital workflow while simultaneously improving the quality of implant-supported prostheses.



IV. Discussion

The superior accuracy of photogrammetry can be attributed to its ability to directly capture implant position without relying on soft tissue or surface scanning. This makes it particularly advantageous in edentulous patients or those with limited reference points for intraoral scanners.

However, limitations include higher initial equipment costs and the need for specific training. Despite these challenges, the long-term benefits in complex implant cases may justify its adoption.

Clinical Implications

- Ideal for full-arch implant restorations
- Reduces prosthetic misfit and mechanical complications
- Enhances predictability in immediate-load protocols
- Supports fully digital implant workflows

Limitations and Future Directions

While photogrammetry shows promising results, further long-term clinical studies are needed to evaluate implant survival rates and biological outcomes. Integration with artificial intelligence and improved software algorithms may further enhance accuracy and accessibility.

V. Conclusion

Photogrammetry is a highly accurate and efficient digital impression technique for dental implant patients. Its use improves prosthetic precision, clinical predictability, and patient comfort, making it a valuable tool in modern implant dentistry—particularly for complex and full-arch rehabilitations.



References

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