Review Article

Photogrammetry: A De Novo Approach in Dentistry

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Abstract

Photogrammetry is emerging as a transformative tool in dentistry, offering high precision and customizability. This review explores its applications in various dental specialties such as Orthodontics, Implantology, Prosthodontics, Conservative Dentistry etc. and also delves into the accuracy of photogrammetry in clinical practice and discusses its potential advancements, including integration with Neural Radiance Fields (NRFs) for enhanced 3D modelling. [2025, 6(1): 15-20]

Keywords: 3D dental model, Dentistry, Photogrammetry.

Introduction

In dentistry, accurate diagnosis and treatment planning are imperative. Traditional plaster models, though widely used, pose challenges in terms of storage, accessibility and precision. Digital technologies, particularly photogrammetry, provide a cost-effective, customizable, and user-friendly alternative for creating accurate 3D dental models (1).

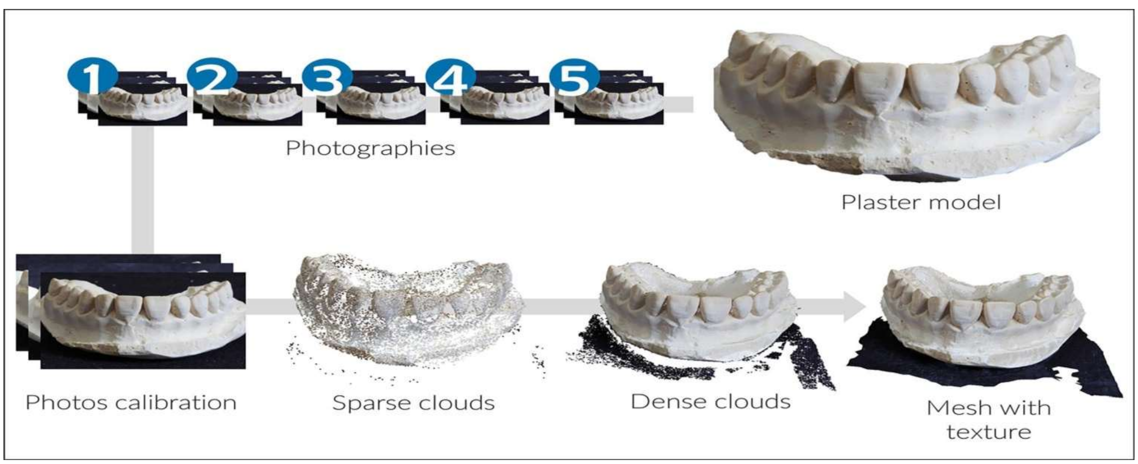

Fig 1: Scanning a Plaster Model using photogrammetry

Principles of Photogrammetry

Photogrammetry involves capturing images from multiple angles and processing them to create precise 3D models. Its application in dentistry has been validated by studies comparing digital and plaster models, demonstrating an almost perfect agreement with Interclass Correlation Coefficients (ICCs) of 0.99 (Fig 1) (1).

Precision of Photogrammetry

Photogrammetry's precision has been validated through studies comparing digital and traditional plaster models. Recent research provides quantitative data that highlights its reliability and accuracy in clinical applications (2).

Measurement	Level	Mean	SD	CV (%)
Height	1.1	7.41	0.07	0.99
	1.2	5.95	0.1	1.71
	1.3	7.44	0.02	0.3
	1.4	6.02	0.02	0.42
	1.5	4.66	0.08	1.65
	1.6	4.44	0.01	0.28
	2.1	7.54	0.03	0.35
	2.2	6.47	0.11	1.76
	2.3	8.23	0.1	1.22
	2.4	6.44	0.14	2.13
	2.5	5.01	0.07	1.3
	2.6	4.57	0.02	0.37
Width	1.1	7.36	0.04	0.48
	1.2	6.47	0.13	2.04
	1.3	7.04	0.04	0.57
	1.4	5.11	0.02	0.49
	1.5	5.63	0.09	1.6
	1.6	8.6	0.07	0.8
	2.1	7.37	0.08	1.02
	2.2	6.37	0.13	2
	2.3	7.29	0.06	0.89
	2.4	5.29	0.04	0.75
	2.5	4.97	0.06	1.23
	2.6	8.28	0.02	0.23
Transverse	1.3	-2.33	4.11	0.13
	1.6	-2.63	6.78	0.17
Midline—	1.3	18.24	0.14	0.77
	2.3	19.17	0.16	0.82

Fig 2: An exemplary model regarding the Key Precision Metrics

1. Mean, Standard Deviation (SD), and Coefficient of Variation (CV)

If measurements from four digital models are created using photogrammetry (P1, P2, P3, and P4) were compared with a traditional plaster model (PM). The Coefficient of Variation (CV), a measure of variability relative to the mean, was observed to be remarkably low. A lower CV indicates minimal variability in the measurements, ensuring consistent results across different models (Fig 2) (2).

2. Interclass Correlation Coefficient (ICC)

The ICC for measurements between the plaster model (PM) and each digital model (P1, P2, P3, and P4) was 0.99, signifying "almost perfect agreement."This indicates negligible differences between measurements from physical plaster models and digital models created by photogrammetry (2).

To summarize regarding its precision, Photogrammetry achieves precision comparable to traditional methods, with the added benefits of digital storage and analysis. The lack of significant differences between the two methods can ensures that digital models can confidently replace physical ones in clinical and academic settings, though a lot of research into this new alley is definitely required to confirm the same with evidence-based literature (2).

Applications of Photogrammetry in Dentistry

Photogrammetry, as described is coming up as a versatile tool with applications across multiple dental specialties. Its ability to produce highly accurate and customizable 3D digital models makes it invaluable for diagnosis, treatment planning, and patient education (3).

1. Orthodontics

Retention of Study Models: The British Orthodontic Society recommends retaining orthodontic study models for 11 years or until young patients reach 25 years of age. Photogrammetry eliminates the need for physical storage by creating precise digital models, which can be archived indefinitely.

Model Analysis: Enables accurate analysis of dental arches, tooth alignment and occlusion without the risk of model deterioration.

Diagnosis and Treatment Planning: Provides a reliable foundation for planning interventions like braces and aligners.

2. Prosthodontics And Crown & Bridge

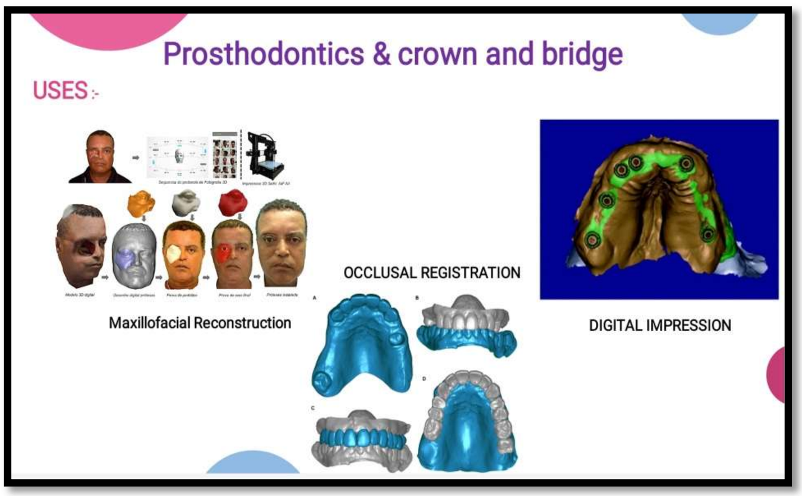

Fig 3: Application of Photogrametry in Prosthodontics and Crown and bridge

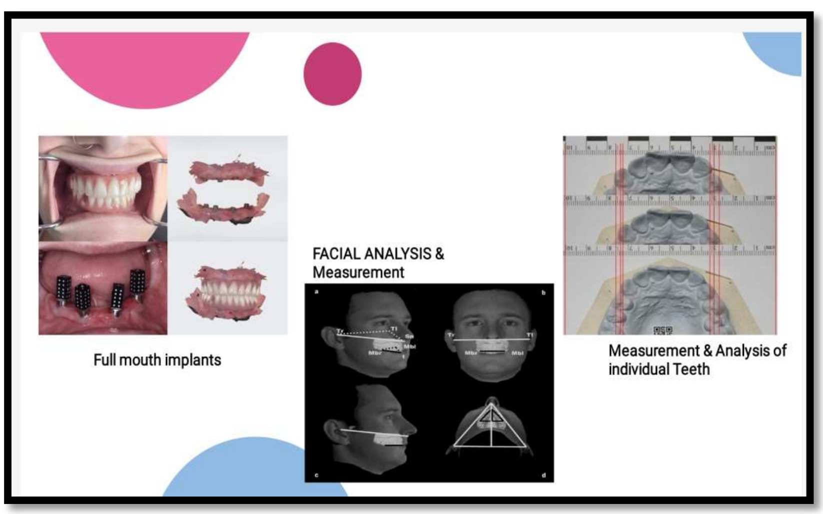

Fig 4: Application of Photogrametry in Facial analysis and Implantology

Maxillofacial Reconstruction: Assists in designing facial prosthetics and surgical templates (Fig 3 & 4).

Digital Impressions: Eliminates traditional impression-making, offering a faster, cleaner, and more precise alternative (Fig 3).

Occlusal Registration: Ensures accurate bite alignment and occlusion for prosthetic devices.

Individual Tooth Measurements: Facilitates the fabrication of crowns and bridges by providing exact dimensions of the tooth structure (Fig 4).

3. Implantology

Full-Mouth Implants: Supports accurate planning and placement of implants by mapping the jaw structure and soft tissues. Digital models created using photogrammetry ensure proper angulation and depth of implants (Fig 4).

Facial Analysis and Measurements: Assists in aesthetic planning for implant-supported prosthetics, ensuring harmony with the patient's facial features (Fig 4).

Measurement and Analysis of Individual Teeth: Enhances precision in designing abutments and final restorations (Fig 4).

Step-by-step procedure for using photogrammetry in implantology:

The application of photogrammetry in implantology is a precise and efficient method, especially for full-arch or 4-in-one implant cases (4).

1. Pre-Surgical Planning

Patient Assessment: Evaluate bone density and gum health using CBCT imaging.

Initial Impressions: Capture intraoral scans or initial impressions of the edentulous arch to understand anatomical landmarks.

2. Image Acquisition

Use a photogrammetry device to capture high-resolution 2D images of the edentulous arch.

Ensure multiple angles are taken to cover the entire arch (including anterior and posterior aspects).

Maintain consistent lighting and stabilize the camera for precision.

3. Data Processing

Process the captured images in photogrammetry software, which stitches them into a 3D model. This model includes precise details of the ridge, gingiva, and potential implant sites.

4. Implant Planning

- Import the photogrammetric 3D model into implant planning software.
- Strategically position four implants:
- Two anterior implants for support.
- Two posterior implants angled for biomechanical efficiency.
- Confirm occlusal alignment and aesthetic symmetry using facial mapping tools.

5. Surgical Template Fabrication

- Use the processed 3D model to design a custom surgical guide.
- Ensure guide holes match the planned implant angulation and depth.

6. Surgical Procedure

- Utilize the surgical guide during the implant placement surgery for precision.
- Confirm implant positions intraoperatively using photogrammetry to detect any deviations.

7. Post-Surgical Data Capture

- After placing implants, use the photogrammetry scanner to map their positions.
- Create an updated 3D model that incorporates the actual implant locations.

8. Prosthetic Framework Design

- Utilize the final 3D model to design a prosthetic framework tailored to the patient's unique anatomy.
- Incorporate occlusal and aesthetic considerations to ensure a natural appearance.

9. Prosthetic Delivery

- Attach the prosthetic framework to the implants.
- Verify fit, occlusion, and aesthetics using the photogrammetric model for reference.

10. Post-Treatment Analysis

Regularly capture digital models during follow-ups to monitor implant stability and prosthetic integrity.

Record keeping

Photogrammetry simplifies the creation of permanent digital records, which are:

Easy to Store: Requires minimal physical space compared to plaster models.

Accessible: Can be retrieved and analysed anytime for follow-up treatments or legal documentation.

Education and training

Patient Education: Visual 3D models enhance patient understanding of their condition and proposed treatments.

Dental Training: Enables students to practice with realistic digital models, improving their diagnostic and technical skills.

Diagnosis and treatment planning

Accurate digital models ensure that clinicians can diagnose conditions and plan treatments with minimal assumption. Particularly useful in complex cases where precise measurements and alignments are critical.

Advantages of photogrammetry

Advantages of photogrammetry are: (5)

Economical: Eliminates the recurring costs of plaster and storage.

Customizable: Adaptable to various clinical requirements.

User-Friendly: Easy-to-operate equipment and software.

High Precision: Provides accurate measurements, as validated by low coefficient of variation (CV) and high ICC values.

Timesaving: Speeds up workflows by digitizing processes.

Disadvantages of photogrammetry

Disadvantages of photogrammetry are: (5)

Cost of Equipment: High initial investment in photogrammetry devices and software can be a barrier for smaller clinics.

Learning Curve: Clinicians and technicians may require specialized training to operate the equipment and process the data effectively.

Time-Consuming for Large Cases: Image acquisition and processing can be time-intensive for complex cases.

Dependent on Image Quality: Poor lighting, unstable cameras, or incorrect angles during image capture can compromise the accuracy of the 3D model.

Limited Real-Time Use: Unlike intraoral scanners, photogrammetry might not provide immediate feedback during procedures

Future Prospects

The integration of photogrammetry with Neural Radiance Fields (NRFs) represents the next frontier. NRFs use machine learning to reconstruct realistic 3D scenes from 2D images, offering unprecedented accuracy and detail for dental applications.

Conclusion

Photogrammetry is revolutionizing dental practices by combining precision, ease of use, and cost-effectiveness. Its applications span multiple specialties, providing clinicians with reliable tools for enhanced patient care. Future advancements like NRF integration promise to further expand its utility, making it indispensable in modern dentistry.

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