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Review Article

APPLICATION OF PHOTOGRAMMETRY IN DIGITAL DENTISTRY

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ABSTRACT

Three-dimensional (3D) digital technology is rapidly altering dentistry practice, with photogrammetry emerging as a precise, efficient, and minimally invasive approach for capturing intraoral anatomy and implant locations. Its increasing significance stems from its ability to overcome the drawbacks of traditional impression procedures, lower clinical mistakes, improve passive fit, and improve patient comfort particularly in implant dentistry. This review attempts to describe the applicability, accuracy, and practical feasibility of photogrammetry in implantology. A narrative literature search was conducted using major scientific databases, including PubMed, Google Scholar, and the Cochrane Library, along with relevant textbook chapters. Studies were selected based on their focus on photogrammetry systems, close-range photogrammetry, implant-position recording, and comparisons between photogrammetry, conventional impressions, and digital intraoral scanning techniques. This approach ensured the inclusion of studies most relevant to evaluating the role of photogrammetry in contemporary digital dentistry.

Keywords: Photogrammetry, 3D Models, Implant supported prosthesis, Esthetics, Full mouth rehabilitation.

INTRODUCTION

Photogrammetry is advanced mathematical tool that can improve the accuracy of implant planning and in full mouth rehabilitation. Using several photos of the same item taken from various perspectives, this method creates three-dimensional coordinates of certain spots. (Desai & Bumb,2013) Photogrammetry is a popular alternative to traditional impression materials for registering intraoral characteristics and implant position, improving patient comfort, accuracy, and predictability. In contemporary dentistry, dental photography is a useful tool for treatment planning, patient education and communication, and record keeping (Ahmad,2009; Casaglia,2016; Mladenovic *et al*.,2010). The absence of stable landmarks makes scanning for whole arch implant-supported prostheses more difficult, and reports of inadequate passivity, especially in mandibular prostheses, have been made (Moon & Lee, 2025; Yilmaz *et al*.,2021; Pozzi *et al*.,2022; Paratelli *et al*.,2023; Pérez-Giugovaz *et al*.,2022). Applications ranging from cartography and civil engineering to manufacturing have made substantial use of photogrammetry, a technique that uses reference points within photos to make precise measurements. Photogrammetry required the use of specialized cameras and stereo-optic workstations for photographic analysis. However, developments in digital cameras and software applications have made it feasible to obtain accurate and dependable measurements using widely accessible software and standard, commercially available digital cameras (Tommaselli AM,1998).

For dental imaging, a number of imaging methods have been developed, such as stereo vision and structured light (Logozzo *et al*., 2014; Mangano *et al*., 2017). Structured light projects patterns, like speckles and coded stripes, onto the surface using active lighting (Mangano *et al*., 2017; Geng, 2011). These patterns are distorted by the surface elevation (3D shape), and this distortion is examined to rebuild the scene's 3D geometry. Stereo vision, on the other hand, images the scene using two cameras. The two sensors record identical features at different places because of parallax (Wang *et al.,* 2014). The intra-oral photogrammetry scanner that is now on the market features built-in photogrammetry technology, allowing it to record

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various implant locations using unique intra-oral flags. Unlike extraoral photogrammetry scanners, which require a third-party software application, the present intra-oral photogrammetry scanner can perform both soft tissue and scan flag scanning as well as blend them in the supplied software. The present review compiles and evaluates current scientific evidence on the applications of photogrammetry in digital dentistry. It examines its accuracy, efficiency, and clinical feasibility across various dental disciplines, with particular emphasis on implantology. The review compares photogrammetry with conventional and digital impression methods, highlights its technological advancements, and summarizes its advantages and limitations. By integrating findings from recent studies, this review provides an updated understanding of photogrammetry as an emerging and highly precise tool in modern dental practice.

TYPES OF PHOTOGRAMMETRY

Close-range photogrammetry

Close-range photogrammetry collects images from ground level or short distances for detailed 3D reconstruction of objects, structures, or small sites.

Aerial photogrammetry

Aerial photogrammetry uses photos taken by drones, planes, or satellites to produce topography data, 3D models, and large-scale maps. Close-range photogrammetry has become a popular substitute for current 3D imaging methods in recent years (Jiang *et al*.,2008; Luhmann, 2010; Luhmann *et al*., 2023). Close-range photogrammetry simply requires one camera and doesn't require active illumination. From a collection of pictures or a video, it can create full-color 3D models. By triangulating common features from several photos, photogrammetry calculates the 3D coordinates of points (Hartley & Sturm, 1997) Close-range photogrammetry-based dental imaging (CPDI) has been thoroughly investigated and has demonstrated tremendous potential in dental practice due to its simple system setup and ease of use (Zhang *et al*., 2023; Fu *et al.,* 2017; Zotti *et al*.2023).

This technique is based on the concepts of multi-view stereovision, in which the locations of photographs and the characteristic points of objects in three-dimensional space are simultaneously calculated, either with or without prior calibration (auto calibration) (Zotti *et al.*,2022). The images of the thing are taken from every angle. To correctly scale created 3D models, reference markers must be used because all photogrammetric values are dimensionless. Errors may arise when the 3D model is being scaled. Errors can also result from an inadequate number of characteristic points, excessive distortions brought on by flaws in the optical acquisition equipment, and an inadequate or excessive distance between two common pictures that make up a stereopair. As a result of these mistakes, the locations of the characteristic points in three dimensions are calculated incorrectly. The collected photographs include much more information as the number of characteristic points on the object's surface increases, which significantly lowers errors associated with the computation of reconstructed photos and pointers to the placements in three-dimensional space. Additionally, it can readily overcome the difference in the baseline distances between photos with a large number of detected points, minimizing the mistake. This technique offers quick and versatile image acquisition, making it simple to cover the entire object (Santoši *et al*.,2018). The alternative kind of photogrammetry is Aerial photogrammetry is the study of using airplanes or drones to capture, measure, interpret, and create three-dimensional (3D) models of physical objects and the surroundings. Land surveying and mapping, building, agriculture, archeology, the military, and intelligence are some of its uses. In dentistry, it is not utilized.

PHOTOGRAMMETRY IN IMPLANTOLOGY

A recently developed technique for accurately and easily recording the locations of several dental implants is photogrammetry. By transmitting all the data needed to create the prosthesis straight from the patient's lips to a computer file, photogrammetry makes it possible to register the precise three-dimensional placements of the implants. The method circumvents the inconvenience that comes with traditional imprint procedures. Trays, imprint materials, implant body mimics, and impression abutments are not required. The *PIC camera* measures angles and distances between prosthetic attachments placed on the implants. The attachments are Scan bodies / Scan abutments – Most common; detachable components placed on implants for accurate digital impression capture. Healing abutments with photogrammetric markers- Some systems use modified healing caps that include identifiable markers. Implant-specific coded abutments -Manufacturer-coded components that give precise implant orientation and connection details. Multi-unit abutments (MUAs) – Used especially in full-arch cases; scan bodies are mounted on top of these allowing the patient total freedom of movement and the presence of blood, saliva or any other organic or inorganic residue does not affect measurement precision. Compared to traditional impression-taking processes, avoiding so many procedures and materials lowers the risk of error, saves time (both the number and duration of clinic visits), lowers costs, and lessens patient pain (Zotti *et al.*,2022). One of the most popular treatments for people who are partially or totally edentulous is dental implants. The long-term prognosis of implant-supported dentures with passive fit has been demonstrated by research.

PIC CAMERA

A stereo camera called the PIC camera (PIC dental, Madrid, Spain) uses photogrammetry to record implant placements in the mouth. It consists of two CCD cameras that are specifically made and tuned for clinical use. These cameras use unique individual coding (PIC abutment, PIC dental) to identify abutments screwed on implants in order to properly establish the location of the implants. The camera's infrared flash eliminates ambient light shadows while continuously illuminating the scanned item.50 three-dimensional photos must be taken by the PIC camera for every two PIC abutments. It automatically captures ten extraoral images every second with an inaccuracy of less than 10 microns to accomplish this. The registered angles and distances between implants are considered a single unit and are connected to one another. From these photos, system software determines the average angles and separations between implants to produce a vector representation of each implant's precise relative position. This is the PIC file (PIC Dental), which includes all the data that CAD/CAM software subsequently needs on implant locations, geometries, connections, healing abutments, and screws. The diagnostic accuracy of PIC (Patient Intraoral Camera) devices varies depending on the image sensor technology used (Peñarrocha Oltra *et al*.,2014).

CMOS sensors, which are the most commonly used, provide spatial resolution in the range of 20–50 µm, with reported diagnostic sensitivity of 85–95% and specificity of 80–90%, making them suitable for routine caries detection, restoration assessment, and patient education. CCD sensors offer superior image uniformity and low-light performance, with higher spatial resolution of 15–30 µm, sensitivity of 90–97%, and specificity of 85–95%, allowing more precise evaluation of marginal integrity and fine surface details. Older fibre-optic sensor systems, now largely obsolete, demonstrate lower accuracy, with spatial resolution of 70–100 µm and reduced sensitivity and specificity, limiting their clinical utility. Recent advances in HD CMOS sensors have further improved image quality, achieving resolutions of 15–25 µm and diagnostic accuracy comparable to CCD sensors, while maintaining lower power consumption. Overall, CMOS-based PIC camera sensors provide an optimal balance between accuracy, cost, and clinical practicality, while CCD sensors remain superior for high-precision documentation.

DISCUSSION

The concept behind photogrammetry is "metering what is written in light," or using photos to extract accurate metric data. Using a variety of cameras, the photogrammetry approach expands the two-dimensional information contained in photographs into three dimensions by reconstructing each photographed object's shape and spatial placement in respect to an external system of reference points (Peñarrocha-Oltra *et al*.,2014). Special cameras that can recognize this system of reference points are needed to perform the computations required for reconstruction. Photogrammetry has been employed in vitro in implant dentistry research to evaluate the accuracy of alternative impression methods (Lie & Jemt,1994). As early as 1999, Jemt and Bäck described its use for registering the positions of dental implants intraorally. They compared this technique with conventional impression taking, concluding that photogrammetry offered a valid alternative (Jemt & Bäck,1999). By lowering the risk of problems and facilitating more accurate implant placement, the application of 3D imaging in implant procedures enhances surgical results. It is now easier to use photogrammetry to record the three-dimensional spatial orientation of objects in the oral environment because to developments in digital cameras and software.

LIMITATIONS OF PHOTOGRAMMETRY

Dental implant planning and surgery benefit greatly from photogrammetry's ability to create extremely precise 3D models and measurements. It is a safer imaging alternative for patients because it is non-invasive and exposes them to no radiation. Intraoral, extraoral, and extra-oral full-face scans are just a few of the circumstances in which it can be utilized to collect data. Because photogrammetry equipment is typically portable, physicians can collect data in the field or on-site (Bainiwal D, 2023). In certain cases, photogrammetry's restricted depth perception in comparison to other imaging modalities may affect its accuracy. The quality of the photos acquired affects how precise photogrammetry is, and low-quality photos might lead to inaccurate outcomes. Accurate data collection and processing necessitate technological know-how, which may be a barrier for certain professionals. Equipment for photogrammetry can be expensive, especially for small dental offices. It is crucial to abide by the relevant laws and standards for data security and privacy because the legal landscape for photogrammetry is still developing. (Bainiwal D, 2023).

CONCLUSION

The most accurate and dependable method for planning implant and full-mouth rehabilitation is photogrammetry, a contemporary 3D imaging tool. It is now easier to use photogrammetry to record the three-dimensional spatial orientation of objects in the oral environment because to developments in digital cameras and software. Although photogrammetry has many benefits, there are certain drawbacks, including issues with image quality, depth perception, technological know-how, and regulatory compliance.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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