

Photogrammetry in Prosthodontics - A Review

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ABSTRACT:

Purpose: To ascertain the clinical benefits of photogrammetry and its various applications in prosthodontics. Dentistry is a field which has a need for precise information about teeth shape, their relative position and their appearance in the face. Conventionally models are used to analyze the arch position and occlusion, and these existing means do not provide adequate presentation. Photogrammetric approach gives solutions for all all-described problems with appropriate accuracy of measurements and high quality data for investigation, documentation and presentation.

Data identification: databases such as Pubmed/ Medline, Google Scholar, Index, EBSCO, Directory of Open Access Journals (DOAJ), SCOPUS, Primo Central Index focusing on photogrammetry and its application in prosthodontics. Articles were selected which would address the stated purpose specifically applications in prosthodontics.

Conclusion: The photogrammetric method of images accretion has been used in various fields of science and industry since long. Its advantages include the simplicity and affordability of technical execution, high accuracy of the obtained data, complete contactless application and the chances for the digital processing of an enormous amount of information over a short period of time, accretion of a virtual model of high accuracy.

KEYWORDS: Photogrammetry, coordinates, 3D models, 2D photographs and objects, visualization

I. INTRODUCTION:

Dentistry is a field of science where correct and adequate information about the morphology of the teeth, their relative position in the arch, occlusion and the overall maxillofacial structures is of utmost importance.[1] This information is useful in all the fields of dentistry whether a preventive or a corrective treatment is to be done including various restorative and rehabilitation procedures. The conventional techniques used for recording this data require fabrication of plaster models by registering impression and then further analysis is done using mechanical tools. The use of 2D images acts as an

adjunct to the analysis process but these images do not provide adequate information about the spatial and three-dimensional arrangement of the teeth as well as surrounding oro-facial structures.[2]

Presently, the use of 3D models for analysis and treatment planning is increasing and provides with better precision and accuracy. So a newer non-invasive technique with better accuracy and good reproducibility is used for registration of all the details of the patient.[3] Photogrammetry is the science of obtaining three-dimensional information from 2D objects. The data is acquired by reflection of light from points on the object in the form of photographs and then the reconstruction of a 3D model from these points.[4] The overall geometric relationship between the points and the image is calculated by using suitable coordinate systems. In this technique a mobile device is used to capture all the images from different heights and angulations and then the data is transferred into a software(Agisoft Metashape) which generates the 3D model.[5]

Photogrammetry has a wide range of applications in medicine as well as dentistry. In dentistry, this technique is used for analysis of facial profile as well as teeth, occlusion and bite registration, jaw relation records, analysis of tooth preparation, verifying the occlusal contacts, complete arch implant prosthesis and evaluation and 3D reconstruction of teeth and face. This article reviews the application of photogrammetry in dentistry and particularly in digitally encircled branch that is prosthodontics.

II. MATERIALS AND METHODS:

The research was done electronically on databases such as Pubmed/ Medline, Google Scholar, Index, EBSCO, Directory of Open Access Journals (DOAJ), SCOPUS, Primo Central Index focusing on photogrammetry and its application in prosthodontics. This investigation aims to make one aware of newer innovative technique called photogrammetry and its application in prosthodontics.

III. DISCUSSION:

In the present article, the applications of photogrammetry has been discussed particularly emphasizing its role in prosthodontics.

- Maxillofacial reconstruction: This approach is used for analysis of the maxillofacial defects and recording adequate details of the defect by means of various reference points as the geometrically complex anatomy of the orofacial structures is difficult to reproduce by conventional means. Also, this non-invasive technique gives better esthetics required for rehabilitation of large defects. The 3D reconstruction of large defects including ocular, orbital, nasal and auricular deformities is possible by means of photogrammetry with better accuracy and color characterization can also be done with high precision.[6,7]
- Occlusal registration: The first step is to place in 3D models of upper and lower teeth arches during a given position according their location and orientation during a mouth. For this aim plaster models are installed in given posture enlist a dental articulator or silicon mould for grouping. Dental articulator is used for registering centric(normal) occlusion. Silicone mould is constructed by dentist during a mouth, jaws being in given position conforming to left or right side occlusion. Then the silicon moulds are placed between plaster teeth arch models providing plaster models being within an equivalent mutual position as real teeth arches during a mouth. during this inclination the front

surface of upper and lower teeth rows is scanned. The scanned front surface of the teeth is then used as a credentials surface for jaw 3D models translating into comparable real jaws occlusion.[1,8,9]

- **Occlusal contacts:** The conventional 2D-analysis methods have various limitations regarding the details about tooth morphology required for analysis of occlusal contacts. Photogrammetry governs 3D positional details of occlusal contacts from 2D-photos. The image is formed using the black silicone method along with the photogrammetric technique that generates facets for image construction. These facets generate a 3D image from the data of occlusal records obtained by 2D photographs. The occlusal surface configuration was reproduced with polygons. The textures of the occlusal contacts were drawn to each of the polygon. Establishment of occlusal facets with 3D polygons from 2D-photos with the help of photogrammetry was a drawing features of this image processing technique. It allowed us for observing better findings of the black silicone method. On comparison with conventional 3D analysis using a 3D scanner, details of conventional 3D models did not duplicate the anatomical configuration. Even though, by integrating the findings of the interocclusal record, the dislocation of mandible and the displacement of periodontal ligaments under occlusal force were reflected in our model. Using the polygons in the conversion of 2D images to 3D images, we would be able to define the relation between the location and direction of the occlusal contacts and facets, which was earlier difficult to detect via conventional methods. Thus, this method of making a 3D polygon model is useful for, finding the inter-occlusal records which considered the jaw/teeth behavior under occlusal force could be observed 3-dimensionally.[10]
- **Evaluation and facial reconstruction:** Use of digital photos of the face became the part of the usual procedure at the planning of the dental aesthetic treatments. Some features like Symmetry, smile line, contour line of the face position of the upper and lower lip, visibility of the teeth etc. can be determined on the frontal images. Photos must be standardized, and the position of the head and distance from the camera precisely determined in order to decrease the possibility of the mistake. At the time of determination of the symmetry of the face and teeth are used imagined horizontal and vertical lines, which could be observed in the frontal and sagittal direction. In symmetry assesment is essential that the line which goes by the mid of the face is homogeneous to the line of the contact of the upper central incisors (interincisal line). Imagined horizontal lines significant in the aesthetic evaluation are line of the hair, line of the eye brow, interpupillary line, interalar line.[11]
- **3D duplication of teeth and face:** Photogrammetric systems used in dental research are of the similar, as the object–camera distance is less than 300mm. The proposition of remodeling a 3D surface by photogrammetry is based on a method called bundle adjustment. This method involves simultaneously refining the 3D coordinates of surface points, the different positions of the camera and the camera’s optical characteristics. virtually, positioning the intra-oral camera at angles α_1 , α_2 , α_3 ... α_{50} to take 50 photographs of the tooth from divergent points of view in a 15 mm radius hemisphere. An overlaying of 60% between the sequential photographs is considered necessary to automatically find some correspondences between the points of a photograph and the subsequent photograph. The supreme results are obtained when we do not change the distance to the tooth between successive photographs. All photograph are unified on the tooth, with approximately half of the adjacent tooth in the field of view. All the obtained photographs are then sent to the Autodesk

cloud via the Internet to be transformed into 3D models. Three uploads are performed separately for each image acquisition series (images of the tooth of interest and adjacent teeth, images of the opposing teeth, and images of the teeth in occlusion). Within 10 to 15 minutes, three reconstruction files can be generated and visualised with ReMake software.[12,13]

- Occlusal analysis: For occlusal analysis, to carry out required section and measurement using teeth arch 3D model specialized software is developed. It supports the following functions: – 3D model visualization in different modes (solid, wireframe, points), – making given plane section of 3D model, – section contours visualization in forms of 2d or 3D curves, – Measuring given parameters in section plane. The software allows to segment the 3D models in a number of ways. Sectioning can be performed manually or in an automatic mode according to chosen reference points. There can be one or more sections, parallel to each other. The sections are depicted as contours on 2D images. Using this software it is attainable to study the resemblance of each prepared tooth contour on a 2D image to contours of the same intact tooth, tooth prosthesis and the opposite tooth and then perform precise measurements on them. Studying and making measurements on sections is the essence of the investigation.[2,14]
- Complete arch implant prosthesis: Photogrammetric technique is used to record the location and orientation of multiple implants and to differentiate the outcome with those of a standard complete-arch impression technique. The fidelity of the photogrammetric method is indistinguishable to CMM, but less for the standard method as contrast to CMM although, the overall measurement precision of the photogrammetric and standard methods is similar. The photogrammetry system allows clinicians to obtain the exact position of dental implants and to fabricate accurate implant suprastructures. This technique provides a panoramic view of implants in an arch and, therefore, is accurate.[15,16,17]
- Detection of facial profile: One of the main objectives of prosthodontic treatment is to improve dental and facial esthetics. The understanding of sentimental tissues of the face in reference to the dentoskeletal tissues is important in esthetic treatment. Investigation of soft tissue facial profile by photogrammetry provides superior details on the facial morphology.[18,19]
- Production of 3D models: Photogrammetric technique have been used considerably in a diversity of regulation to give rise to models across a extent of scales, from landscapes to small objects Within physical anthropology, it is viable to take precise assessment of larger skeletal elements, such as crania, employing photogrammetric models instead of the original specimens. gross tooth shape was captured effectively using SfM photogrammetry and hold up foregoing studies that have found moderately low levels of variation between point clouds of small articles derived from SfM and SLS systems, the adjacent approximation of the overall size and shape of the SfM virtual models is close to the 0.1 mm accuracy that has been put forward as necessary for virtual models to hold diagnostic value for clinical treatment.[20,21]

- **Tooth shape:** Tooth assessment (odontometry) are carried out for numerous technical and experimental approach, including dentistry. Present-day techniques are being increasingly found on 3D model use that dispenses broad possibility in disparity to estimation on actual objects: teeth or their plaster imprints. The principal advantages come out alongside with the exertion of new measurement methods which furnish the needed degree of non-invasiveness, precision, sake and details. Tooth measurements have been always regarded as a time-consuming prospects, even more so with use of new methods due to their ample chances. This is where computerization becomes crucial for further evolution and implication of measurement techniques. In our investigation computerization in obtaining 3D models and automation of measurements provided vital data that was directed to suggest recommendations for tooth preparation – one of the most higher level clinical procedures in prosthetic dentistry – within a equally short period of time. The indigenous photogrammetric 3D reconstruction system allows to bring about to 3D models of dental arches, duplicate their termination, or occlusion, and to perform a set of characteristic measurement in automated manner.[2,22]
- **Measurement of dental casts:** 3D virtual dental models constitute an alternate, suitable way of recording and maintaining occlusal data on hard drives. Multi-baseline digital close-range photogrammetry(MBDCRP) is a evolved technology to acquire 3D geometric information for real-world objects from stereoscopic image and has potential way in orthodontics to record plaster casts three-dimensionally. With a holographic sensor SLR digital camera, photos of dental casts can be gripped using a multi-short baseline method. The images are then imported into a programme designed for computerized space analysis. 3D models of dental casts without extreme horizontal overlap can be reconstructed by a novel method of MBDCRP profitably. The specific build on 3D digital models are replicable. Without expensive hardware and software, MBDCRP is an distinct way to reserve and estimate dental models without the requirement of a special room to keep plaster casts, mainly worthy for private dental clinics and community clinics.[3]
- **Facial analysis:** The facial emergence is biased as it is contrived by various agents such as race, ethnic, gender, socio-cultural, and age. Due to the dissimilarity in conception, clinicians should contemplate the suitable normal value of the thorough facial emergence is based on the patient's race and nationality when planning a treatment. complete facial appearance is affected by the soft tissue that covers the skeletal tissue. Facial profile is one of soft tissue component that has to be examined for prosthodontic diagnosis. Soft tissue of the face needs an independent evaluation in addition to the skeletal and dental inspection in order to wind up a full-scale diagnosis and treatment planning of the face. The reliableness of the photogrammetry, mainly for the measurement of the lips and mouth was evaluated, strongly advocated and suggested that the sake of photogrammetry can be increased by developing superior techniques. Photographs provides a good assessment of agreement between the external craniofacial structures, including the soft tissues, in addition to providing dependable measurements. Through photogrammetric examination of the facial profile, proportionality, angular and linear measurements can be gained.[1,6,23]

- Impression of multiple implants: The method used for recording the positions of multiple dental implants by displaying the positions of multiple dental implants using a system based on photogrammetry. The concept of photogrammetry contains of 'metering what is written in light,' in other words, getting reliable metric details from photographs. The photogrammetry technique enlarges the two-dimensional information given by photos into three dimensions; using different cameras, the shape of every photographic objects and their location in space are reconstruct in connection to an external system of reference points. To make the salient calculations for reconstruction, special cameras are needed that are able to identify this system of reference points. Photogrammetry permit the recording of the exact three-dimensional locations of the implants, moving all the information need to fabricate the prosthesis right from the patient's mouth to a computer file. This technique keep away the disruption along with standard impression techniques. Impression abutments, implant body analogues, trays and impression materials are not needed. The PIC camera measures angles and distances between prosthetic attachments set down on the implants, allowing the patient total freedom of motion and the existence of blood, saliva or any other organic or inorganic remnants should not affect measurement precision. The clinical demand of this novel photogrammetry system for registering the location of multiple implants allowed the rehabilitation of a patient with utmost maxillary free end edentulism with a prosthesis of optimal fit. The prosthetic fabrication process was imposed, fast, simple for the dentist and satisfying for the patient.^{24,25}
- Analysis, planning and visualisation: Dentistry is a field which needs imposed information about teeth shape, their relative position and their emergence in the face. This statistics is essentially important for various dentistry fields such as orthodontia, teeth treatment, denture construction. prevailing system for inspecting mutual teeth arches position (occlusion) use plaster teeth arches casts and distinct mechanical tools which allow recording the occlusion. To Investigate and visualize the outermost appearance of teeth arches only 2D images are used which do not furnish full and acceptable presentation. So existing means do not give required accuracy and are not suitable for a dentist. Proposal of Photogrammetric technique gives solution for all described problems with relevant accuracy of measurements and high-quality data for investigation, documentation and presentation. A prop of new techniques for teeth occlusion registration and analysis is proposed based on seeking teeth arch 3D model instead of a plaster mould. The photogrammetric techniques are well developed and are used for computerized patient face and teeth arch 3D models creations, for occlusion registration, treatment planning and documenting.[1,26]
- Facial and dental symmetry: Maxillary anterior teeth have presiding role in the interpretation of the dento-labial complex by their position, shape and size. If these are in harmony with other components of orofacial region, they significantly contribute to the aesthetics of the face. Symmetry is one of crucial component in the conception of dento-facial aesthetics. Imagined horizontal lines significant in the aesthetic evaluation are line of the hair, line of the eye brow, interpupilar line, interalar line and intercommisural line. Parallelism of those lines generates horizontal symmetry and merge the face composition. Interpupillary line is used as reference line in the assessment of incisal and occlusal plane. concerning the aesthetic detail, ideal should be considered when inter pupilar line and the line drawn on incisal edges of incisor (incisal line) are parallel and both will be vertical to the line which goes on the mid of the face.[11,27]

IV. CONCLUSION:

The photogrammetric system of images accession has long been used in various fields of science and industry. Its advantages include the clarity and cost effectiveness of technical execution, high accuracy of the obtained data, complete contactless application and the chances for the digital processing of an wide amount of information over a short period of time, acquisition of a virtual model of high accuracy. The developed techniques allow fast and precise information generating full 3D model of a teeth arches in given occlusion and a multi-resolution face 3D model for treatment planning and visualisation. The developed software gives to a dentist new effectual and convenient means for teeth occlusion study, treatment planning and documenting. This technology is a boon for prosthodontics, While this technology still does not provide enough precision or proven accuracy for incorporation into the treatment flow, it is an fascinating tool for the diagnosis, planning, and storing of documentation. More studies are needed before this methodology can be designated for a clinical application, such as for the preparation of guides for guided implant surgery. upcoming agreements should be tested with the acquisition of new tools, such as the integration of target references, other photographic settings and alternative software.

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