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Review

Stereo-Photogrammetry for Impression of Full-Arch Fixed Dental Prosthesis—An Update of the Reviews

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Abstract: Photogrammetry (PG) appeared as an alternative for multiple implant impressions. Stereophotogrammetry is a more sophisticated alternative to PG, which estimates the 3D coordinates of the points of an object, making the process quicker and more precise. A search in PubMed MEDLINE, PMC, and Google Scholar was conducted to find systematic reviews published in the last 10 years. The PICdental® camera (IDITEC NORTH WEST, SL; Torrelodones, Spain) is a stereocamera that records implant positions in the mouth by means of photogrammetry with the objective of registering and obtaining a viable, reliable, and direct digital impression of the positions of the multiple implants. The use of photogrammetry via PiCdental® camera as an alternative to digital impression for multiple implants is an easy and trustworthy technique that permits an adequate fit without prosthetic complications.

Keywords: dentistry; implantology; dental implants; photogrammetry; dental impression technique; CAD/CAM

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1. Introduction

The dental rehabilitation that involves multiple dental implants is one of the great challenges in the implantology specialty. The passive fit of an implant structure is crucial to achieving long-term successful rehabilitation [1–3]. The inappropriate fit of an implant-supported superstructure can induce mechanical complications like the loosening of screws and a fracture of the implant components; biological ones like the resorption of marginal bone, peri-implantitis, and failure of bone integration. Therefore, obtaining the master and viable prosthetic structure depends on the precision of the implant impression, which is one of the decisive factors that influence a good definite result [4,5].

The conventional impression method includes the direct (open tray) and indirect (closed tray) techniques, as well as splinted and non-splinted impression copings. In the literature, there is not unanimity about which impression technique is more accurate to transfer the spatial relation of the implants placed in the jaws to the master model. There is no consensus either about when to use or not use the transfer splint or about the quality and type of impression material in multiple implant impressions [6–9].

Moreover, it was reported that the conventional impression is slower (more time-consuming), sensitive to the operator, difficult to transport and store, and uncomfortable for patients. Also, mistakes can be introduced during the whole complex process due to the inherent properties of the impression material and the fusion material in obtaining the metallic structure [10].

Since the introduction of the manufacturing process assisted by computers, better known as CAD/CAM, different approaches have been developed to obtain precise digital implant impressions. There are two alternative methods available to capture data: indirect capture of the data (digitalized casts in the laboratory, made from conventional impressions); and direct capture of the data (intraoral digitalization). Therefore, the intraoral scanners (IOSs) became popular due to their advantages over conventional impressions, directly acquiring digital data from the mouth of the patient [11].

Even though recent evidence suggests a high level of predictability for the scanning of a single implant [10], some studies reflect that in other certain situations, the IOSs results were less accurate (e.g., various implants, patients with no teeth). As there is a decrease in precision as the scanning interval increases, it was concluded that the IOSs were less precise for multiple implants, especially in total fixed implant-supported prostheses [12–16]. In other studies, the IOSs had equal or even better accuracy than the conventional methods [17]. Other factors that affected the accuracy of the IOS acquisition also included the inter-implant distance, the depth, the angle of the implant, the brand of the scanner, and the experience of the operator [12,18].

The importance of the passive adjustment of full-arch fixed dental prostheses (FAPs).

The passive fit of the implant-supported full-arch fixed prosthesis is defined as the simultaneous and steady contact of all surfaces without tension before the functional load. The fit has to be as accurate as possible between the implant structure and the prosthetic infrastructure to maintain bone integration, avoiding complications such as the fracture of various components of the implant systems, pain, and marginal bone loss [19,20]. In other words, the "passive fit" is the minimum gap in the connection between the implant structure and the implants without causing tension, namely the lack of total tension between implants and the structure [11,21].

The perfect fit can never be reached in the screwed prosthesis since the structures can always deform, even in ideal adjustment conditions. The tension in the structure is an inevitable consequence of the screw tightening method, and therefore, some authors suggest revising the definitions of "passive fit" without tension [22,23] and changing the term for "active fit" to refer to the desired setting in the final position.

Regardless of the conventional or digital workflow, manufacturing errors and distortions, especially in the construction of complete full-arch structures, remain inevitable [24,25].

Brånemark et al. [26] were the first to quantify the passive fit of implant structures and to propose that the misfit could not exceed 10 μm. Jemt and Lie [27] reported that a misfit of approximately 150 μm was unacceptable when the screw resistance test was introduced [28]. However, it has already been reported that the structure discrepancies of the FAPs of up to 10 μm were considered non-passive, and the discrepancies in the interface varying from 38 to 345 μm between implants and structures were suggested as clinically acceptable. Some studies evaluate the fit with all the screws tightly fastened for their measurement. In such situations, it is believed that vertical discrepancies would be eliminated, even when they vary from 30 to 500 μm [18,19]. In these cases, the fitting could be obtained under tension, and when the prosthesis is subjected to occlusal loading, a range of different force vectors can result in fatigue and complications [28]. It is difficult to establish what threshold of discrepancies is tolerable. Because the definitions of the passive fit and measurement methods used are many and are not standardized in studies. It is generally assumed that the allowable discrepancies are assumed to be between 10 and 150 μm [22,24,29–31]. Today's literature supplies insufficient evidence about the effect of misfit in the interface of implant prostheses in the clinical results of screwed fixed prostheses over implants. Nowadays, there is still no international consensus about the exact level of misfit that should be considered clinically acceptable for implant structures, as well as for the definition of "passive fit" from a biomechanic perspective [22,28,32].

The Sheffield test, or "test of 1 screw", is one of the most popular tests for the clinical evaluation of the passive fitting of the structure [21,33–35]. When the screw of the outermost abutment is completely tightened without creating a discrepancy among the rest of the abutments, the structure is considered to passively adjust. This method is applied specifically to FAPs structures, in which the size of the discrepancy tends to increase at the abutments level. The "screw resistance test" can also be used. It consists in tightening the screws one by one, starting from the implant, which is closest to the midline, until the initial resistance is found when tightening a screw. If tightening that screw requires more than half a turn to reach the ideal fit, the structure is considered inadequate (not passive). For assessing gaps that are at the supragingival and subgingival levels, saliva or loading-revealing pastes and waxes can be used. This test can also be implemented by analyzing a tomographic computerized X-ray [9,21,28]. Obtaining accurate impressions is undoubtedly one of the critical steps in the manufacture of implant-supported prostheses, since lack of precision can affect the passive fit of the construction of an implant-supported structure [20,22,30,32].

The conventional and digital workflow: impression techniques to obtain the master casts.

a. Conventional impression with resources of trays and impression materials: direct and indirect techniques.

The first step to guarantee the passive fit is to make a precise impression and transfer the 3D positions of the implants to the master cast. The impression technique, impression material, splinting/non-splinting of impression copings, splinting materials, number, and angle of implants are the factors that affect the impression precision [20].

In the conventional workflow to make an impression of the FAPs implants, impression material and impression copings that either fit directly into the implant or screwed to the abutments multi-unit are needed. These impression copings should reproduce the spatial positions of the implants placed in the jaws. Currently, there are two ways to take this kind of conventional impression:

(1) The indirect technique (or "transfer technique") requires a closed tray and impression copings that generally are fabricated in plastic (like snap-on type). Once the impression is defined, the tray is removed from the mouth, leaving the impression copings fixed to the impression material. The analogous system fits into the impression copings and is retained on the tray so that the master cast can then be carried out.
(2) The direct technique (or "pick-up" technique), which requires an open tray and transfer copings screwed to the implants. To remove the impressions, the retention of the screw must be loosened only after the final setting of the impression material. This is achieved through holes in the impression tray that are located on top of the impression coping or customized tray for each case. The "pick-up" impression copings are frequently splinted to each other with acrylic resin or other materials or structures (bars, straws, or dental floss) before adding impression material. The rigid connection of multiple impression copings is applied to avoid horizontal movements during the impression process because the impression material is elastic. The implant analogs are directly screwed to the transfers that are retained in the impression material [3,7,29].

Branemark was the first to introduce the immobilization (splinting technique) of the transfers to stabilize and prevent rotational, horizontal, and vertical movement. Branemark reported that the application of acrylic resin Duralay® to an adapted orthodontic wire, steel pin, or dental floss can be used among the coping transfers for the implant impressions [3,7,36].

The splinting technique is one of the most important methods cited in the literature [7,8,29,37–39], gaining popularity through the years and proving to be more accurate; however, there are still opposite opinions [8,39]. Some authors identified potential problems with the splinting technique, like the fracture of the connection among the materials used for splinting and the impression copings, in particular, due to polymerization shrinkage. The auto-polymerization resin is the most popular material, followed by plaster impression, dual-polymerization resin, orthodontic wire [36], prefabricated auto-polymerization bars, compost resin photopolymerizable, and bisphenol A-glycidyl methacrylate (bis-GMA) [40]. This is in agreement with the studies carried out by Menini et al. [9,39]. The shrinking of the splint is directly related to the splint paste, especially when impressing a full arch where there are long empty spaces. This can negatively affect the dimensional stability of the resin used, affecting the accuracy of the fitting of the implant prosthesis.

To minimize this, cutting off the splint is suggested, and then join the cut parts after 24 h by adding more resin so as to restore the splint and, at the same time, minimize the polymerization shrinking. However, this process does not represent the ideal solution in cases of immediate extraoral loading implants, especially due to the lengthening of the work time and the necessity of a second appointment.

Furthermore, angled implants constitute a challenge in terms of impression accuracy. Due to anatomical and aesthetic limitations, it is not always possible to place the implants parallel to each other. It is known that in the presence of 4–6 implants, the impressions made from parallel implants are more precise than those made when angled implants are present. In cases in which various implants are available and there is a disparallelism greater than 15°, the use of the open tray technique and the splinting of the impression copings are recommended.

In addition, various studies demonstrated that the direct technique of the open tray is more precise when the transfers are rigidly immobilized in the impression of multiple implants [7,20,29,37–39].

The most used impression materials for FAPs are polyethers (PEs) and polyvinisiloxanes (PVSs) for their excellent physical and chemical properties. In spite of there being a great debate in the literature about which impression material is more adequate for the implant master cast, both PE and PVS are recommended, without differences [3,7,18,41]. However, when dealing with various implants, the use of impression materials with a high level of rigidity (like plaster or rigid PE) seems to be favorable to achieve precision and avoid the displacement of the implant component during the removal of the tray [3,7,18,41].

Many studies have exhaustedly tried to reproduce the two techniques (direct and indirect; splinting or non-splinting), and they have not found which technique is better in terms of transferring the three-dimensional positions of the implants [9,41].

When using the conventional procedure, there are too many intermediate steps to obtain the master cast. In all these steps, in which human factor is involved, performance protocols are necessary for the correct procedure. The distortion of the impression in the FAPs can be produced by various factors, like excessive flexibility of the material of the impression, misfits among the fixation of the transfers and the implants, the design of the coping transfers impression, premature removal of the mouth tray or the wrong removal direction in relation to the implant axis, or movements of the coping transfers, and the heterogeneous plaster dilation [7,20,42,43].

b. Digital intraoral impression with scan body resources

Digital impressions are a new method for achieving implant positions and substitute conventional impressions and plaster models [44,45]. Intraoral scanners (IOSs) are devices for capturing direct optical impressions in dentistry. They project a light source (laser, or more recently, structured light) onto the object to be scanned, in this case the dental arches, including prepared teeth and implant-scanned body. The images, captured by imaging sensors, are processed by the scanning software. The IOS is able to scan a tooth, a prepared tooth, or a scannable implant abutment (scan bodies that have a cylinder form and are screwed to the implant). The three-dimensional position of the scan bodies (which transmits the corresponding position of the implant in the dental arch) is registered by the IOS, and the digital data obtained can be documented and manipulated by using computer-aided digitalizing software (CAD). The result of such a procedure is a virtual master cast, exhibiting the scan bodies. Based on the position of the scan bodies, the prostheses are virtually projected and can be manufactured using computer-aided manufacturing (CAM) technology. Depending on the optical scanning technology, titanium oxide powder may be required on intraoral surfaces [17,29].

The IOSs represents the base of the digital workflow for the fabrication of FAPs that manage a set of data called Standard Tessellation Language (STL) archives and that are used for the fabrication of provisional prostheses, or definitive ones supported by implants [46]. The images of the dental tissues, as well as the scan bodies, are captured by imagery sensors and processed by the scanning software, which generates cloud points. Those cloud points are then triangulated by the same software, creating a 3D surface model (mesh). Technically, the IOSs can be integrated into a closed system, generating only proprietary archives, or they can be opened, producing archives (.STL, .OBJ, and .PLY) that can be used by any kind of CAD software. In addition, digital exams can reduce patient discomfort and are more efficient regarding the time and simplifying the clinical procedure, eliminating plaster casts, and providing better communication between the dentist and dental technician or patients. Moreover, the IOS decreases the risk of cross infection by reducing direct contact with the oral structure and saliva, especially in the presence of the COVID-19 pandemic, by eliminating the plaster casts. It also reduces the chair time during the impression procedure and minimizes or eliminates the repetition of the impression process [17,45].

Even though evidence suggests a higher level of predictability for scanning of a single implant and for challenging cases where the angle and the depths of the implants are present, some studies report inconsistent results in patients with various implants with greater extensions of the quadrants or in patients who are toothless [10]. Additionally, in some other studies, the IOSs accuracy is equal to or greater than that of conventional methods [17], and even other studies report a decrease in precision as the size of the scanning interval increases and conclude that the IOSs were inadvisable for multiple implants [5,32,47–49].

The IOS conditions in vivo can significantly affect the precision and trueness of the linear and angular parameters when the distance between the scan bodies increases, making additional scanning devices necessary between the scan bodies to provide precisely satisfactory scanning in the edentulous arch when there is a great distance between implants because the scanner requires an irregular format without adjacent repetitive surface structures, which makes digital scanning of the full-arch of an edentulous patient a challenging, especially for an inexperienced operator [13,32,45,50–54]. The official indications of the IOSs do not include complete arch implant impressions, but many studies assess this possibility. There are several factors that could affect the accuracy and precision of the IOSs, such as long edentulous spans (lacking references), mobile tissues, the number of implants, or the stitching of the 3D images to produce the STL file [54].

Photogrammetry (PG) appeared as an alternative for multiple implant impressions [50,55]. The PG technique has demonstrated a high level of precision in three dimensions (3D) in other fields such as topographical architecture, naval engineering, and automobile fabrication [11,56,57], as well as in other areas of dental medicine. In a simpler example, photogrammetry is based on the distance between two points that are found on a parallel plane of the photographic image that can be determined by measuring the distance between them if the scale of the image is known. Stereo-photogrammetry is a more sophisticated alternative to photogrammetry, which estimates the 3D coordinates of the points of an object, making the process quicker and more precise [11,33,50,51,58,59].

The PICdental® (IDITEC NORTH WEST, SL; Torrelodones, España) is an extra oral scanner that uses the fundamental principles of stereo-photogrammetry with the objective of registering and obtaining a viable and direct digital impression of the positions of the multiple implants.

This review aimed to assess the precision of the stereo-photogrammetry PICdental® camera for full-arch fixed implant-supported prosthesis in the comparative context between the conventional analogical and digital impression. Stereo-photogrammetry PICdental® is a modern tool; that is why we consider updating the systematic reviews on it and checking the state of the art.

2. Materials and Methods

The databases PubMed MEDLINE, PMC, and Google Scholar were selected to support this review. The following keywords were used: "Dental Implants"; "Photogrammetry"; "Dental impressions technique"; and "CAD/CAM", along with further controlled vocabulary MeSH (Medical Subject Headings) terms.

The search included systematic reviews published in the last 10 years. Manual searches from the obtained articles were performed to increase the search outcomes. The following inclusion criteria were applied: systematic reviews and meta-analysis that had interventional characteristics and information on results related to the keywords, published in English. Any article that was not a systematic review was excluded (e.g., RCTs, interventional or in vitro studies, short communications, and letters to editors). Patents without extended evaluation measures, non-English language articles, articles without any evaluation outcomes, and articles published outside the selected period were excluded.

The reviewers screened the papers obtained independently, and only eligible studies were included. Any conflict regarding an article was resolved by discussion among the reviewers.

3. Results

A total of 56 articles were extracted from databases within the selected period (no articles from an online search were found). Six articles were eliminated because they were duplicated. Screening the titles of the remaining 50 articles resulted in the exclusion of 45 articles according to the inclusion criteria. After analyzing the abstract, three articles were excluded. The reason for excluding the articles was that they do not match with the objective of the current review. Finally, two articles were included. The systematic reviews of Rutkuna 2023 and Hussein 2023 are included [60,61].

Five of the nine articles included in the systematic review of Rutkuna et al. [60] published in 2023 evaluated the PG. Only one article (Zhang et al., 2021) [62] showed a high risk of bias. The systematic review of Hussein et al. in 2023 [61] included 20 articles. No analysis of the risk of bias was possible.

4. Discussion

Providing tension-free fitting between implant connections and prosthesis structures is a requirement for the medium- and long-term success of FAPs rehabilitations. This situation can only be achieved with the execution of prosthetic treatment with a good passive fit. The passive fit depends on all clinical and laboratory procedures involved in the manufacturing of the prosthesis, which must be developed precisely to keep the margin of error and inaccuracy to a minimum at each stage of the procedure [63–67]. Therefore, when screwing a structure, tensile stress and flexible power are produced on the dental implants and consequently the transfer of power stress to the bone support of jaws. It was demonstrated that the lack of fit between the prosthesis and the implants leads to a loss of implants due to a lack of bone integration [23,31,42].

The correct transfer of the position of the implants placed in the arch to the master model depends on the impression taken. This is a fundamental step in obtaining the implant-supported structures with a good passive fit. In regard to the conventional impression, there is some controversy in the literature about which impression technique is more reliable. (direct or indirect technique). When a cast model involved three or fewer implants, there was no difference between the techniques, while with four or more, the open tray technique with splints was recommended [68]. However, the conventional impression is time-consuming, operator-sensitive, difficult to transport and store, as well as uncomfortable for the patient. Furthermore, mistakes can be introduced during the complex process due to the inherent properties of the material of impression and the duplicating materials for the master cast [8–10,41].

In contrast to the conventional impression techniques, CAD technology uses reverse engineering to acquire the data that is digitalized. The digitalization procedure can be with or without contact. The IOSs use a probe scanner that projects a light source over the object being digitalized, in this case the dental arches, including the prepared teeth and scan bodies. The digitalization procedure without contact involves a PG scan [42]. Reports about IOSs concluded that they are superior in accuracy relative to the conventional impression technique. This fact collaborates with the hypothesis that the direct laboratory scan of a plaster model produces better results when it comes to accuracy. However, this reality does not make the clinical work easier for the confection of the FAPs [9,17,50,63,64]. In the in vitro study of Stimmelmayr et al. [64], the mean fit discrepancy of 39 μm is reported when the scan was conducted directly in the mouth. Another workflow aspect in implant dentistry that can cause small imprecisions is the correspondence of the scan body with the virtual library of the CAD software. If the original digitalization does not have good quality, this can result in an incorrect correspondence of the scan body and an error in the analog position of the virtual model [49].

The main problem with the IOS currently used in clinics is the loss of precision that occurs due to the so-called "overlap", which is an alignment of the scan between common areas. The literature does not support the use of IOSs for the fabrication of long-span restorations, such as fixed full arches supported by natural teeth or implants [20,51].

To achieve the required accuracy in the registration of the position of multiple implants, PG is the unique technology that allows the registration of the precise position of the implant. PG is a technology that all IOS producers need to perform equipment calibration [66]. Therefore, the precision of the IOSs depends on the PG, which is considered the most precise method for measuring the 3D position of an object without contact [42–49,52–54,65–74].

Flügge et al. [29] in a systematic review and meta-analysis found discrepancies in the fit between digital and conventional impressions in the implant prosthesis, where the linear deviation was greater than 170 mm and the angular deviation greater than 0.5 degrees in all devices and technical assessments. Such problems are reduced with PG because the discrepancies with this technique are smaller; they were reported to be from 5 mm to 5.6 mm, or as small as 4 mm in favorable conditions [63,75].

Recent research shows that PG devices had higher precision than IOSs, suggesting that this technology could be useful for manufacturing full-arch implant-supported prostheses [76,77]. In addition, devices like PICdental®, as they only capture the 3D position of the implant, do not create stitching distortions, not considering the ambient light, the saliva, or the long-span edentulous areas. However, intraoral scanning is needed to capture the soft tissue and the intermaxillary relationship [77].

The use of photogrammetry in dental medicine: in search of accuracy in full-arch fixed prostheses.

Photogrammetry (PG) is the science and technology of taking measurements through photographs. It is a mathematical technique based on the generation of 3D coordinates to define the spatial arrangement of an object, identifying the reference points in various different angled images of the same object [65,66]. The PG technique is capable of making a 3D reconstruction of real objects by overlapping two dimensional (2D) images and taking measurements from photographs [67]. This method has been largely used in mapping applications as well as in the civil engineering industry to take precise measurements using reference points in photos [65,67].

In dental medicine, PG studies date back to research from Anderson, Lamb, and McGarrah [78], in which the quantity of marginal distortion on the area of the tooth's surface, absolute dental movement, and the wear and tear of the composite restorations were assessed. Later on, Lie and Jemt [50] incorporated PG in studies of fitting tests of the prosthesis. They analyzed the distortion of the implant structures with the PG technique. Since then, the technique has been implemented in the implantology field to measure the position of the implants, the structure of the prosthesis, and the microgaps between both in various situations through in vitro studies. The three-dimensional accuracy of measurements from the center point of the implant with this technique was reported to show a mean discrepancy of 12 μm in a laboratory situation, which compares favorably with conventional impression/master cast manufacturing. So that is why it was suggested that PG could be an aid or even a substitute for the conventional impressions for the fabrication of milled titanium framework structures by a Computer Numeric Controlled (CNC) device [50,55,68–70].

Basically, the technique consists of taking various photos from different angles and planes, and then the images are uploaded and merged by software that configures the reconstruction process in a semi-automatic way. The software matches the uploaded photos and creates a cloud of scattered points identifying the 3D position of the common points in two or more photos. The PG follows the collinearity principle: the point of the object, the point of the image, and the center of the camera lens in turn should be aligned. According to this method, the coordinates of an unknown 3D point in an object of interest (in this case the implant) can be determined by the spatial interaction of two or more images taken from different angles and planes [71].

Various materials and methods have been reported in these studies for the assessment of the accuracy of photogrammetry. Stuani et al. and Fu et al. [66,72] reproduced a plaster cast, transforming it into a virtual 3D archive by obtaining 2D photographs. They conclude that despite not having obtained a proven accuracy for its incorporation in the flow of clinical treatment, it is an interesting tool for diagnosis, planning, and archiving as well as documentation. It is suggested that more studies are needed so that these methodologies can be implemented in clinical applications, such as for the development of guides for guided surgeries on implants. Bergin et al. [67] concluded that the artifacts produced by reflective targets made the digital scan of the software more difficult. Despite the limitations of the in vitro studies, they concluded that the technique is a highly dependable tool to measure the location and orientation of the implants and suggest the use of opaque ceramic tiles because they produced better results. Bratos et al. [65] reproduced the same study, with a difference of using a mannequin of a typodont and three types of lip retractors with the intent of simulating a clinical situation, this time using targets fabricated in polymerizavel resin. The authors concluded that a reduction in accuracy and precision can be explained by the partial obstruction of visibility and access to the capture of the image and by the use of fewer registered targets in the image. As more targets are added, the better is the acquisition of the accuracy and precision of the data. Both studies found similarities in the accuracy if compared to the conventional impression.

The reviews included in this study concluded that PG has similar accuracy for registering implant positions in full-arch edentulous situations as intraoral scanning [60] and that PG was used efficiently as an implant transfer system and could replace the conventional methods in the implant clinical workflow, although photogrammetry did not have sufficient accuracy to be used as a 3D scanner [61]. Also, they identified two main applications of the PG: the capture of 3D coordinate data of implant positions (that can be converted to a file for manipulation by a dental CAD software program) and the digitization of the tissue images for planning or designing prostheses in the future [61].

Despite the aforementioned advantages, the PG technique does not seem to have a friendly workflow. The reason is that many measurements need to be taken from the correct calibration of a photographic camera as well as the references that serve as guides for the processing of the image by the software. Optical aberration, distortion of sensor equipment, and incorrect lens configuration can cause image alteration in the original pixels, altering the geometric results and causing the distortion of the final image. These parameters require technical and extra-operative knowledge that can limit the use of the technique in the day-to-day life of dental practice [66].

The precision of the PiCdental® camera in obtaining a digital impression.

The Position Implants Correctly (PIC) (PICdental®, Madrid, Spain) is a stereo camera that registers the positions of the implants in the mouth through PG. It is composed of two charge-coupled camera devices (CCD) specifically designed and optimized for dental clinical use, which determines with precision the position of the implants through the identification of the abutments screwed to the implants with a unique individual code (PIC abutment®, PICdental). The camera possesses an infrared flash that constantly lights up the object, digitalizing it while eliminating the shadows that occur with environmental lights. PICdental® captures 50 3D images for each two PICabutment®. The system is capable of obtaining 600 images in less than 60 s. This requires 10 extra oral photographs per second with a margin of error of less than 10 microns [73].

The PiCdental® camera scan is carried out in the following manner: the photogrammetric abutment is designed in the form of a flag with 4 white dots in its interior that are projected for being recognized by a stereophotogrammetric camera. The PICabutments® are positioned in different forms in each implant abutment for unique identification features. These in turn have been screwed in with a 15 N/cm torque. The PICabutments® is placed 15–30 cm away from the patients' mouth with a maximum of 45º angle in relation to the PICabutments®, reducing the environmental lighting to obtain a better scan [73]. However, the PICabutments® does not need to be used in a specific buccal or tongue position, and either it is necessary to position the stereophotgrammetric camera aligned with the abutment.

A portable computer with PICPro® (Madrid) software manages the data obtained. The software calculates the average angle and distance between implants from those photos, obtaining a precise relative position of each implant in a vector format. This is PICfile®, which contains all the information about the positions of the implants, geometries, connections, healing abutments, and screws, which are then demanded by CAD/CAM software [59].

It is important to note that the PICPro® software allows the patient to move the head during the impression procedure without affecting the digitalization process. If any type of movement occurs in the position of the abutments, the software detects it and alerts the operator. The system interrupts the process to avoid producing imprecise 3D information; this guarantees that only precise archives are processed [11].

This is how the first dataset is obtained. Then, the healing abutments are placed to make an impression of the arch in alginate to obtain a plaster cast. The plaster cast is then scanned with a 3D scanner, so a digitalized cast is obtained in STL format with topography and information about the patient's soft tissues. An IOS can also be used to digitalize that information [59]. After recording the position of the implant with a camera, it is aligned and merged with the digitized image using one of the CAD software tools (DentalCAD; Exocad®, Darmstadt, Germany) that automatically makes a better fit. It is also possible to improve the alignment through a three-point registration by the Best-fit® software (version 3.8.1.31), which uses an algorithm that matches as many points as possible. This entire process is responsible for transferring the relative position between the implants to the digitalized model provided by the soft tissue format, thus leaving the interfaces of the future prosthesis well related to the patient's gums. The antagonist arch is also digitized and inserted into CAD software to provide occlusal references [11,33,34,74]. Among the potential advantages offered by the introduction of CAD in the design of structures for FAPs is the instant elimination of errors followed by a fast fabrication approach and the reduction of fabrication time, the inherent repeatability, and the elimination of variation between operators [42].

A systematic review reported that the PIC system's trueness ranged from 10 to 49 µm and precision ranged from 5 to 65 µm. A recent study reported that scanning distance impacted the trueness of the complete-arch implant scan captured by using the PG system tested, but no differences were found in the scanning precision. Three scanning distances were assessed (20, 30, and 35 cm). The results show that the 30 cm distance obtained the highest linear trueness [62]. However, Orejas-Pérez in 2023 [54] found that the PIC system was not affected by the distance between implants nor by the arch type. As long as the two lenses can visualize the reference abutments and the rest of the PIC Transfers®, the registration will be completed regardless of the soft tissue.

Although it seems to be identical, it should be differentiated between PG technology and the PIC system; they share similar physical principles, but in the PIC system, there is software linked to the cameras carrying specific algorithms adjusted to the oral environment [54]. Additionally, it would be interesting in the future to match PICdental both with smartphone applications (Pascadopoli M, et al. 2023) [79] and artificial intelligence (Kaya E et al.) [80] in order to improve data and knowledge about the reliability of this technology in the daily clinical practice.

This review has some limitations. As PG is a relatively recent tool in dentistry, there are few systematic reviews of the current subject. In addition, they incorporated few articles with a high risk of bias, probably because the published papers have very different methodologies that make them not comparable. More prospective, randomized, and controlled clinical trials are needed to better evaluate the PG technology in the field of full arch implant impression.

5. Conclusions

The PG technique via the use of a PiCdental® camera as an alternative to digital impressions for multiple implants is an easy and trustworthy technique that allows an adequate fitting without prosthetic complications. Even though it offers various advantages over conventional impressions and other digital impressions. The PG technique does not reproduce the information of the hard and soft tissue. Therefore, an additional impression for this purpose is necessary.

Although PG seems to be a reliable tool for implant impressions, similar to those obtained with conventional impressions and scanners, more prospective, randomized studies are needed because the scientific evidence from the systematic reviews published till date is scarce (and there are no meta-analyses).

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