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EFFECT OF DIFFERENT SCANNING PROTOCOLS ON THE RETENTION OF DUPLICATED MAXILLARY COMPLETE DENTURE (A CROSS SECTIONAL STUDY)

Sawsan Maged Fadl* *and* Reham A. El Sharabasy **

ABSTRACT

Aim: The purpose of this study was to compare the effect of three different scanning techniques used for duplication of maxillary complete denture on the denture retention.

Materials and Methods: Ten completely edentulous patients with the age range of 55-65 years old who received new complete upper and lower dentures and recalled after one month to assess their satisfaction of the upper denture retention were selected. For each patient, the maxillary denture was digitally duplicated using three different scanning techniques so three duplicate dentures and three groups were generated according to the way of scanning: Group 1: Duplicated maxillary denture using a desktop scanner. Group 2: Duplicated maxillary denture using a cone beam computed tomography (CBCT). Group 3: Duplicated maxillary denture using an Intra-oral scanner (IOS). The data were then sent to the 3D printer for digital manufacturing of the prostheses. Retention force which is the maximum force required to completely dislodge the maxillary denture was measured using a digital force gauge with a capacity of 100 N, a minimum unit of 0.1 N, and an accuracy of 0.5%. The device's hook engaged the ring and exerted a dislodging force until the denture was pulled out of its place. The measurements were repeated five times at five minutes intervals for each denture base and the average value was identified.

Results: It was found that mean of retention value of printed duplicate dentures was 45.40, 38.10 and 32.10 N for group 1, 2 and 3 respectively, a significant difference between the groups was found ($p < 0.001$). When comparing between groups, it was found that the mean value of retention of group 1 is higher than that of group 2 and 3, on the other hand, the mean value of retention of group 3 is the lowest between all groups. A significant difference was found between (group 1 & group 2) with p value (=0.002) and a high significant difference was found both between (group 1 & group 3) and between (group 2 & group 3) with p value (<0.001).

Conclusion: Digital duplication of complete denture using the desktop scanner yielded the most retentive denture followed by using the CBCT and the least retentive denture was that made using the IOS.

KEYWORDS: Duplicate denture, CBCT, IOS, Desktop, Retention

* Lecturer of Oral and Maxillofacial Prosthodontics, Faculty of Dentistry. Ain Shams University, Cairo, Egypt
** Lecturer of Removable Prosthodontics, Faculty of Dentistry, Beni-Suef University, Beni Suef, Egypt

INTRODUCTION

The 'copy denture technique' is used in today's dental practice to provide replacement of dentures with cost efficiency.[1,2] A copy denture technique provides the advantage of rapid adaptation by the patient to the familiar shape of their original denture. Several ways have been proposed to produce the templates for the copy denture.[3] All these traditional ways constitute a physical impression of the denture to produce a mold and a subsequent pouring of a cast or template in wax or acrylic of the patient's denture.

Recently, complete dentures could be duplicated with satisfactory results using either conventional or digital methods. To create a mold, which is the negative reproduction of the complete denture, elastomeric impression materials or irreversible hydrocolloids were routinely used. In order to complete the duplication procedure, the auto-polymerizing acrylic resin is packed into the mold. Impression materials are frequently restrained and supported by stock trays or denture flasks.[4] The conventional method is demanding and time consuming.[4] The entire duplicate process needs to be finished quickly when using the irreversible hydrocolloid impression medium to prevent deformation. [5]

Many areas of dentistry, including the creation of complete dentures (CDs), have undergone modernization because to CAD/CAM technology. The use of CDs in a digital workflow has several benefits, including accelerated clinical procedures and digital data collections, which are vital for senior patients with weakened health who could require denture copies or remakes.[6] The three fundamental phases of CAD/CAM technology are data gathering (image scanning), data processing (CAD), and prosthetic manufacture (CAM).

Digital impressions are quicker, easier to store and distribute than analog ones, have better patient acceptance, and provide a real-time, 3D previsualization of the scanning surfaces.[7]

Different digital scanning methods, such as cone beam computed tomography (CBCT), extraoral optical scanning, or intraoral scanners (IOS), have been proposed to duplicate existing CDs. [8,9] Dentistry relies heavily on intraoral scanners (IOSs) as the foundation of a computerized process for prosthesis planning and manufacture. [10] Intraoral scanners (IOSs) are revolutionizing dentistry through the advent of digital dentistry. [11-13] In all IOS devices, the light projection is captured as discrete images or videos, which are then stitched together by a program when the POI (points of interest) are identified. Furthermore, a video made up of many images per second in a continuous data flow or a wave analysis can be used to create a surface reconstruction. [14]

There are a variety of extraoral scanners on the market, including laser, blue light, and white light scanners. White light scanners have a good scanning speed but lack repeatability and error occurs particularly in scanning narrow and deep areas, while blue light scanners have higher precision due to shorter wavelength, so it produces fewer errors and has greater scanning repeatability. Laser scanners have slow speed of scanning and low initial repeatability and use a line pattern. [15,16] Studies have shown that extraoral scanners is able to reach an acceptable accuracy level. [17]

On the other hand, CBCT enables the digital creation of a dental cast without the need for a traditional imprint, resulting in less pain and anxiety for the patient.[18] Considering its technological advancement and expanded applicability, it is an alternate strategy.[19] In situations when IOS is not an option, it may be a technique to digitize the dental arch, despite the insufficient reproduction of surface anatomical information it offers.[20]

Both cone-beam computed tomography (CBCT) and an optical scanner can be utilized to digitize a complete denture. [21] When CBCT is employed, the full denture is digitalized in the Data Imaging and Communications in Medicine (DICOM) file format and then transformed into the Wavefront Object (OBJ) or Standard Tessellation Language (STL) file formats.[8] Using an optical scanner, a complete denture's intaglio and cameo surfaces can be scanned separately and combined into a single STL file[9] or continuously scanned by rotating the entire denture. [16] There may be a role for denture replication using intraoral scanners.[20]

A complete denture can be created using subtractive (milling) or additive (3D printing) manufacturing techniques after digitization. Removable dental prostheses have been created using a variety of 3D printing techniques, such as digital light processing (DLP), stereolithography (SLA), fused deposition modeling (FDM), and Polyjet. [21-23]

For the entire denture to be successful, retention is crucial. [24] Retention is based on anatomical characteristics including the size, shape, and resilience of the edentulous ridges as well as on how well the denture base is extended and fitted to the tissues that support the denture. [25] The establishment of physical forces produced by a thin, uniform salivary film and the development of a negative pressure are made possible by the close contact between the base and the underlying tissues. [25]

The retention of duplicated maxillary complete dentures has not been compared in any trials, as far as we are aware. This study compared the effect of several scanning techniques on the retention of maxillary duplicate dentures. The null hypothesis states that different scanning techniques have no impact on the retention of duplicated maxillary complete dentures.

MATERIAL AND METHODS

Ten patients between the ages of 55 and 65 who were entirely edentulous were chosen from the outpatient clinic of the prosthodontics department of the dental school at Beni-Suef University. The research protocol and informed consent were approved by the university's clinical research ethics board; their approval number was (REC-FDBSU/06042023-01/AS). Each patient signed the informed consent form and consented to take part in the trial.

Sample size:

Before the study, the number of patients was determined after a power calculation performed using G*Power[26] version 3.1.9.7 based on the results of a previous study **(Maniewicz et al., 2022)**[27]. To apply a two-sided statistical test and reject the null hypothesis that there is no difference between groups, a power analysis was created. By adopting an alpha level of (0.05) and a beta of (0.2), i.e., power = 80% and an effect size (d) of (0.69) calculated based on the results of a previous study. The predicted sample size (n) was (30 dentures and three different dentures will be measured for each case, so the total number of patients is 10), i.e., 10 dentures per group. To detect different retention values of duplicate complete dentures between the three groups.

Inclusion and Exclusion Criteria

The inclusion criteria were mainly selecting a patient who received new complete upper and lower dentures and recalled after one month to assess their satisfaction of the upper denture retention. For each patient, assessment of retention was done by the operator through examining the borders extension and by trying to pull it out. Also, by asking the patient about the degree of satisfaction of retention based on previous study [28]. The chosen patients were pleased with the retention of their upper dentures.

Additionally, patients with little to no soft tissue or bony undercuts, adequate salivary flow, and an Angle class I maxillo-mandibular relationship were chosen. Patients with the following conditions were not included: significantly resorbed maxillary ridge, torus palatinus, V-shaped palatal vault, and restricted mouth opening.

For each patient, the maxillary denture was digitally duplicated using three different scanning techniques so three duplicate dentures and three groups were generated according to the way of scanning:

Group 1: Duplicated maxillary denture using a desktop scanner.

Group 2: Duplicated maxillary denture using a cone beam computed tomography (CBCT).

Group 3: Duplicated maxillary denture using an intraoral scanner (IOS).

In this crossover study, each patient received three types of duplicated dentures, each patient served as a control for himself. The same operator constructed all the dentures.

The group 2 volumetric dataset was archived in DICOM (data imaging and communications in medicine) format. The DICOM files were transferred into standard tessellation language (STL) file formats using an implant planning program (coDiagnostix; Straumann, Andover, MA, USA). On the other hand, the volumetric data in group 1 and 3 were directly stored as STL files.

The resulting STL files in the three groups were used to additively manufacture digitally duplicated denture bases of printable Resin liquid (Dental Sand A2, Harzlabs, Russia) using the 3D printer (Photon, Anycubic, China).

Identification of the geometric center of the maxillary denture for subsequent measurement of retention:

Geometric center of the denture was determined digitally by automatically calculating the volume of the denture, dividing the 3D object into voxels and automatically determine the center of the 3D object by CAD software (Meshmixer, Autodesk, USA) (Fig.1 a & 1 b). [29]

Using the CAD software, a virtual hook was inserted at the polished surface of the denture at the predefined geometric center after finding the geometric center. (Fig.1 c).

Scanning of the denture:

In Group 1:

The maxillary complete denture to be duplicated was sprayed with an anti-glare spray (Okklu-Exac dent-e-con, Germany), then it was fixed to the rotary table of the desktop scanner DOF Freedom HD (DOF, Seoul, Korea) scanner of accuracy level of 15 μm by using sticky wax. Utilizing two 5.0 MegaPixel cameras and the unique stable scan stage (SSS) technology, this scanner gathers data utilizing structured light (white LED light). The cameras can move above and around the scanning model thanks to the SSS system. While the model is immobile, the cameras and lights spin around the scan plate's center, making it possible to efficiently and swiftly (in less than 50 s) record all of the model's details.

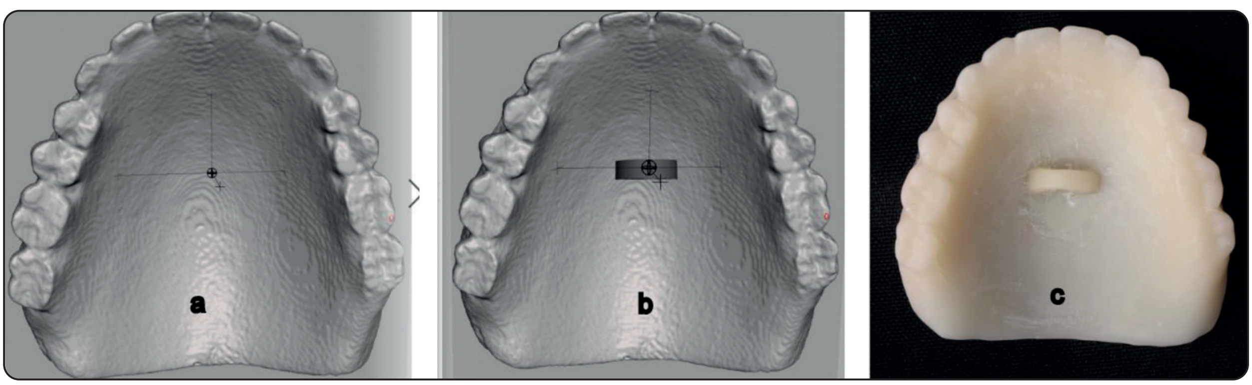

Fig. (1) a & b) Identification of geometric center on the software c) Printed denture with hook at the center .

The scanner has a 5 μm accuracy that has been certified. (Fig.2) The optical scanner was equipped at the focal point of the denture to digitize its surface topography. The rotation movement of the table was determined through the scanning performance of the scanner and processing speed of the computer. Scanning of the intaglio and cameo surfaces was done. The intaglio surface was scanned following the scanning of the cameo surface. Although the cameo and intaglio surfaces were scanned independently, the areas within 5–10 mm adjacent to the denture extensions were included in both scans. Two individual scans were combined using these overlapped regions. The output data was exported as an STL file and then modified using a different program, an open-source CAD program (Autodesk Meshmixer, USA).

In Group 2:

Scanning of the maxillary denture was done using I-CAT next-generation scanner (Imaging Sciences International, Hatfield, PA, United States). (Fig.3) It operates at a tube voltage of 120 kVp, tube current of 5 mA, voxel size of 0.2 mm, field-of-view of 16 ×6 cm and scanning time of 26.9 seconds. The scanned denture was exported in DICOM file format and then converted to STL file format using the free (InVesalius 3; modeling tool) with a custom threshold (between -72 and 348).

In Group 3:

The maxillary denture was scanned using an intraoral scanner (CS 3800, Carestream Dental, Atlanta, GA, USA), which is a structured LED light scanner with a field of view that was enlarged to 16 mm x 14 mm. This will make scanning smoother; it has an improved depth of field up to 21mm. It is light in weight (only 240 gms) with anti-fogging technology. It is speedy because the Intelligent Matching System™ enables the software to rapidly join the scanned images and continually build the mesh without pausing. To enable scanning even in the most challenging places, it is outfitted with replaceable and autoclavable tips of various sizes and orientations. It is an open IOS that generates open files (PLY, STL) that can be processed by any dental CAD and does not require the usage of powder. (Fig.4)

The cameo and intaglio surfaces of the complete denture were scanned, and the margins of the denture were used for their superimposition. These scanned data were exported as an STL file then was imported into free downloadable CAD software (Meshmixer; Autodesk, USA) for further processing where both data of the cameo and intaglio surfaces were combined into one image, The border was smoothed using the "smoothing boundary" command and the gap between the cameo and intaglio surfaces was filled. Each STL file was then sent to the 3D printer for digital manufacturing of the prosthesis. (Fig.5)

Fig. (2) Scanning by the desktop scanner

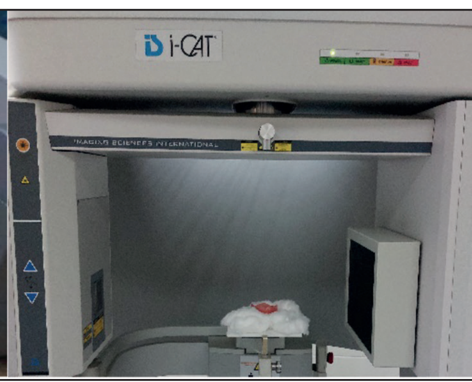

Fig. (3) CBCT scanning

Fig. (4) The IOS

Printing the dentures

Three maxillary duplicate dentures were created for each subject in the following manner: The 3D printer (Photon, Anycubic, China) was loaded with a 3D-printable Resin liquid (Dental Sand A2, Harzlabs, Russia), printing began with a build angle of 45 degrees, and printing thickness on the z-axis was set to 50 microns. Supports were chosen so as not to interfere with the denture's fitting surface. (Fig.6). The supports were taken off after printing, and the printed dentures were cleaned for ten minutes in an ultrasonic bath with ethyl alcohol to remove extra resin. According to the manufacturer's instructions, the denture bases were post-polymerized for 40 minutes using a UV polymerization machine (bre.Lux power machine 2, Bredent, Germany). Using a cutting plier (Cutting tool; Hakko Corp.), the supporting structures of the duplicated denture were detached. The duplicated denture was then polished using lab equipment (Ultra Denture System; Brasseler USA). (Fig.7)

Measurement of retention

The denture was kept in water for 24 hours prior to measurement. A digital force gauge with a capacity of 100 N, a minimum unit of 0.1 N, and an accuracy of 0.5% was employed (HF-100 Digital Force Gauge, Jinan Hensgrand Instrumentation Co., Ltd., Jinan, China). Using the zero button, the display was calibrated to zero and the device was adjusted with the peak hold option chosen, the desired adapter tension hook linked to the sensor head, and the peak hold option selected. The patient was seated in an upright position in the dental chair keeping the mouth half open and lips relaxed. To allow the delivered dislodging force to be almost perpendicular to the denture base, the patient was directed to tilt his or her head backward until the palate and maxillary ridge were at approximately 45 degrees to the floor. The denture was placed in the patient's mouth for five minutes prior to taking measurements to allow for base adaption. The device's hook engaged the ring and exerted a dislodging force until the denture was pulled out of its place. (Fig.8) The highest force required to completely dislodge the maxillary denture was used to calculate the retention force. For each denture base, the measurement steps were carried out five times at five-minute intervals, and an average result was recorded. The same operator conducted all measures at the same time of day.

The results were collected, tabulated, and statistically analyzed to compare between the groups.

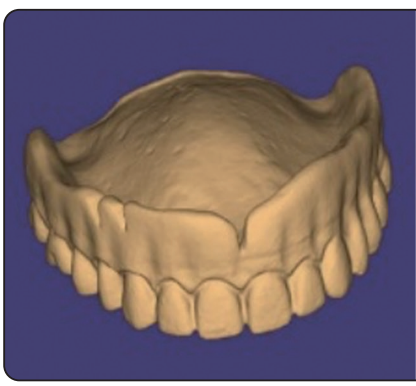

Fig. (5) STL file of the denture

Fig. (6) Printing the denture.

Fig. (7) The three printed dentures

Fig. (8) Retention measurement using the digital force gauge device.

RESULTS

Statistical methods

Data were coded and entered using the statistical package for the Social Sciences (SPSS) version 26 (IBM Corp., Armonk, NY, USA). Data was summarized using mean and standard deviation. For comparison of serial measurements within each patient repeated measures, ANOVA was used **(Chan, 2004)**.[30] Post Hoc test: Tukey's test was used for multiple comparisons between different variables. The significance level was set at p≤0.05 within all tests.

Values of retention of each group and the comparison between the three groups (as shown in table 1 and figure 9):

It was found that the mean value of retention of printed dentures of group 1 (desktop scanner) was (45.40±3.89) N, followed by mean value of retention of printed dentures of group 2 (CBCT) was (38.10±1.20) N and the mean value of retention of printed dentures of group 3 (IOS) was (32.10±1.66) N, a significant difference between the three groups was noticed where ($p < 0.001$).

When comparing between the three tested groups, it was found that the mean value of retention of group 1 is higher than that of group 2 and 3, on the other hand, the mean value of retention of group 3 is the lowest than that of other groups. A significant difference was found between (group 1 & group 2) with p value (=0.002) and a high significant difference was found both between (group 1 & group 3) and between (group 2 & group 3) with p value (<0.001).

TABLE (1): Mean, standard deviation (SD), range and p value of retention (N) for comparison between groups:

Groups	Mean±SD	Range	P value
Group 1	45.40±3.89 A	40-49	
Group 2	38.10±1.20 B	36-40	<0.001
Group 3	32.10±1.66 C	30-35	

p-value <0.001 is highly significant.

Different capital letters indicate significant difference at (p<0.05) among means in the same column.

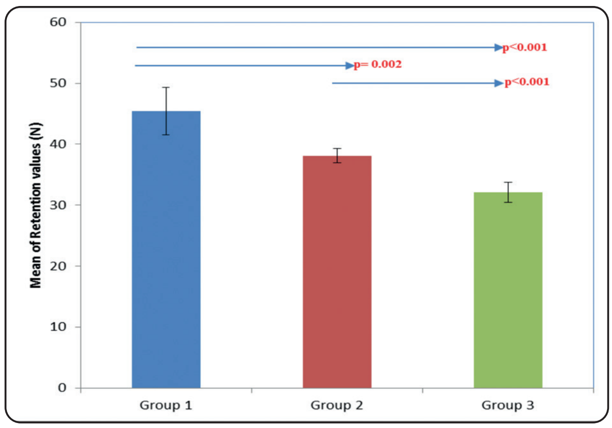

Fig. (9) Comparison between groups according to Retention values (N).

DISCUSSION

Based on the findings of the present study, the null hypothesis was rejected that the different scanning techniques to duplicate the maxillary complete denture have the same effect on the retention, and the results revealed statistically significant difference between them.

To the authors' knowledge, this is the first in vivo approach to compare the retention of printed duplicated dentures obtained from different scanning techniques (desktop, CBCT and IOS) of the patient's existing complete denture.

Many indications for duplication of a satisfactory complete denture were documented such as preservation of tooth size and arrangement, denture extension, shape of denture-bearing areas and occlusal schemes [4,31]. It can also serve as a radiographic template for implant treatment planning and be modified into a surgical template for computer-assisted surgery. [32,33]

The traditional ways of producing the copy dentures produced inherent inaccuracies mainly due to setting contraction of the materials used. [34] An alternative technique to produce the copy denture template through optical scanning and 3D printing has been advocated as it holds the possibility of being more accurate. [35]

Data acquisition step is very important for digital fabrication of complete denture as it predicts the final denture accuracy and fit. [36]

We focused on measurement of retention in our study as retention significantly impacts patient satisfaction and prosthesis success evaluation, [37] it also affects masticatory performance, speaking ability, and patient quality of life. [38, 39]

In this study, the selected patients had healthy mucoperiosteum, for preventing denture base movement and false records during retention testing. [40] Also exclusion of presence of bony or soft tissues undercuts was done to remove the effect of mechanical factors on the retention. [41]

After one month of use, the retention of the patient's conventional maxillary denture was evaluated to allow the denture to settle and the patient to establish the necessary neuromuscular control. [42]

To improve the surface optical qualities of the denture, an occlusion spray was applied. The occlusion spray with an average particle size of 5 μm does not have any notable effects, even if it may change the surface's proportions and add a layer of another material to it. [43,44]

Identifying the accurate location of the geometric center is crucial for testing the retention of maxillary complete denture. In this study, the geometric center was determined digitally as this is a more accurate method and for standardization between the tested groups. [45,46]

Previous study on denture retention determined the geometric center of the maxillary denture by drawing imaginary two lines from the canine cusp tip on one side to the pterygomaxillary fissure on the other side. [47] this method had a lot of drawbacks, as setting of canines may differ from one denture to another even for the same cast or patient. In addition, determining the two points of the line may have a bias. Another study located the geometric center of the intersection of two hypothetical lines. The first line, called the midline, ran between the incisive papilla anteriorly and the fovea palatine posteriorly, while the second line, called the contact line, extended horizontally between the second premolar and the first molar bilaterally. [48] This method's drawbacks were, setting of premolars may differ from one denture to another even for the same cast or patient. In addition, in case of denture duplication, lack of patient cast, and absence of anatomical landmarks make determining the second line a problem. In the current study, volume of the denture was determined automatically, the 3D object (denture) was divided into voxels and the center was determined automatically without any bias.

3D printing was used in this study. This technique involves successive photosensitive resin layers and UV light polymerization, allowing material conservation and accurate printing of complex geometries. [49-51]

Before making the retention measurements, in order to maintain the peripheral seal, the patient was positioned upright in the dental chair with his mouth open and his lips relaxed. The imparted dislodging force was almost perpendicular to the denture base since the palate was at a nearly 45-degree angle to the floor. The denture was then placed in the patient's mouth, where it was left for five minutes to adjust, and then a dislodging load was applied. (52)

In this clinical study, retention was evaluated by a pull-out test that was used in several other studies.(53,23,54) Retention measurements for each patient were done at the same time of the day for the three groups to avoid changes in the topography of the mucosa that occur throughout the day which may affect retention values.

In our study, values of retention of dentures constructed from digital files obtained from desktop scanners were higher than that obtained from both CBCT and IOS respectively and these results were statistically significant. These findings may be attributed to the level of accuracy of different scanning techniques which subsequently influences the retention of dentures. In numerous previous studies, poor scanning accuracy was found to adversely affect the fit of fixed restorations. (55-57)

Under the correlation between accuracy of the scanning and its effect on retention of the final prothesis, the results of our study come in alignment with a previous in vivo study demonstrated the use of a variety of procedures to produce digital models with clinically acceptable accuracy; nonetheless, the desktop scanner group was found to have the highest accuracy in complete arch scans, followed by the CBCT and intraoral scanning groups, in that order. (58)

In numerous earlier investigations, the accuracy of intraoral scanners for whole arch scanning was assessed.(59-62) Five intraoral scanners and two desktop scanners were examined for accuracy in complete arch scans as part of an in vitro investigation. The results, which support our findings, showed that the desktop scanners were more accurate than the intraoral scanners. (62) Another study indicated that the accuracy of CS3600 IOS scanner is lower than desktop or equal if the range of scanning 5-teeth is used, and accuracy declines with expanding the scan range. All scans performed by desktop scanners were confirmed to be within acceptable limits. (61)

In their investigation, Braian and Wennerberg(59) assessed the accuracy of five different intraoral scanner types in a variety of arch situations. It was determined that intraoral scanners, particularly for edentulous patients, exhibit low accuracy for complete-arch scans. The acquisition method or stitching technique used by the majority of IOS may be the cause of IOS's inability to scan complete arches with high precision. These scanners use the best-fit algorithm for image stitching, ensuring object's geometry meets acceptable requirements as in posterior teeth which have complex occlusal surfaces, making alignment easier. Simple scanned areas may cause deviation in image stitching. These findings could explain the least retention values for the IOS group in the present study.

The degree of retention and patient satisfaction level were evaluated in a clinical study after constructing complete dentures by using desktop scanner, intraoral scanner, and conventionally constructed CDs. It was concluded that 3D printed dentures digitally made by IOS expressed the least retention force and patient satisfaction level compared to the other two groups and these results came in agreement with our results. (63)

In contrast to the findings of our study, Wesemann et al (64) compared the accuracy and time efficiency of an indirect and direct digitalization workflow for orthodontic use, they suggested that the most accurate results were obtained by the desktop scanners, but TRIOS intraoral scanner showed comparable results for orthodontic demands.

The results of a clinical study comparing the accuracy of implant surgical guide manufactured using three different techniques: intraoral scanner, desktop scanner, and CBCT cast scan, revealed no statistically significance difference between the three tested groups. [65]

CONCLUSION

Within the limitation of the study, digital duplication of complete denture using the desktop scanner yielded the most retentive denture followed by using the CBCT and the least retentive denture was that made using the IOS.

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