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Research Article

The Effect of Different Scanning Protocols on the Retention of Digitally Constructed Complete Denture Bases

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Abstract

Aim: This cross-sectional clinical trial with ten completely edentulous patients compares the retention of two groups of complete denture bases. Group A denture bases fabricated by final impression digital scanning and group B denture bases fabricated by master cast digital scanning.

Methods: After taking primary impressions closed-mouth impression technique was done and scanned then the impressions were boxed, poured and the resulting master casts were scanned. From each group a denture base was fabricated by additive manufacturing technique and the retention of each denture base was evaluated intraorally by using digital force gauge.

Results: The readings were recorded, tabulated and student's t-test (unpaired) was used to identify the difference between the two scanning groups' retention values. The significance level was set at $P \leq 0.05$. The data revealed that impression scanning group had slightly higher values of retention than cast scanning group even though there was no statistically significant difference between the retention of the two scanning protocols.

Conclusion: within the limitations of this study it was concluded that both extraoral digital scanning protocols has no effect on the degree of complete denture base retention.

Keywords

Digital Denture; Digital Impression; CAD/CAM Dentures; Impression Scanning; Additive Manufacturing Technique

Declaration of Conflicting Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Institutional Review Board Statement

The study was conducted according to the guidelines of the Ethics committee of Ainshams, and approved by the Institutional Review Board Ethics Committee of Ain Shams University (protocol code FDASU-RecIM121810 and date of approval 19\12\2018).

Introduction

For more than 400 years conventional complete dentures were considered the common treatment option for completely edentulous cases to avoid further residual ridge resorption and malnutrition. Complete dentures can be constructed using different techniques and different types of

materials during the laboratory and clinical procedures. The determinant factor for choosing the most efficient technique and material is the resulting intimate mucosal adaptation of the prosthesis with minimal dimensional changes and distortion during fabrication. Good adaptation will result in good stability, support and retention. However, the complexity of the laboratory and chair side procedures and the drawbacks of the materials used made the computer technology more demanded in removable Prosthodontics as explained by L. Peng and N. Janeva et. al.[1,2]

According to Russo and Salamini [3], the digital complete denture workflow also known as computer-aided design and computer-aided manufacturing (CAD/CAM) was successfully used over the last decades. It presents several advantages to the patient and the clinician. Normally, conventional complete dentures require five appointments with a lot of material waste and many hours of patient's, clinician and technician time. Digital workflow can be done in two appointments saving time, effort and material. In addition, patients' records are digitized and stored on the software for any future need. The patient can have an identical prosthesis in case of fracture or lose without the need to make new records. Matsuda et al. [4] suggested that this process will allow the clinician and technician to use a high-value, quality-controlled materials

Schwindling and Stober [5] explained that the preliminary step of the digital workflow is data acquisition and the production of a 3D virtual replica of the edentulous arch, thus the digitalization. This procedure is proceeded by the designing (CAD) and manufacturing (CAM) of the prosthetic restoration. The most crucial step to obtain a well fitted retentive denture is data acquisition. This step can be done directly from the oral cavity by intraoral scanners or indirectly by using extraoral scanners for scanning an impression or the resultant cast. Digitizing the impression step by intraoral scanning overcomes the conventional method shortcomings such as bad taste of impression materials, gag reflex, nausea, discomfort, Allergic reactions and air bubbles entrapment in the impression as describes by Ali et al. [6]. Yet, many studies criticized the ability of intraoral scanners to record soft tissue in completely edentulous cases, thus the process of digitalizing complete denture still requires the different drawbacks of conventional materials and techniques in impression making. Therefore this research was prompted to evaluate the retention of permnant denture bases obtained by scanning the final impression and scanning the produced cast by extraoral scanner and comparing both methods retentive values.

Patients And Methods

Ten completely edentulous male patients with age range of 55-65 were selected from the Out-patient clinic of Prosthodontics department, faculty of dentistry, Ain Shams University. The university's clinical research Ethics board approved the research protocol and the informed consent. All patients agreed to participate in the study and signed the informed consent. For each patient two upper denture bases were constructed one by additive manufacturing technique obtained from digital scanning of final impression and the other one from digital scanning of master casts. Scanning, Designing and 3D printing steps of the denture bases were carried out in the digital Prosthodontic solution center, Prosthodontics department, faculty of dentistry, Ain Shams University.

Careful clinical and radiographic examinations and evaluation of the patient was done to exclude any conditions that may cause difficulties during intra-oral retention measuring such as torus palatinus, V shaped palatal vault, prominent median palatine raphe, flabby or knife ridge. Also patients with severe bony or soft tissue undercuts, and limited mouth opening were excluded.

Maxillary and mandibular primary impressions were made using suitable size stock tray and irreversible hydrocolloid impression material (Tropicalgin Italy, Normal Set) then study casts were obtained. Custom trays were constructed short 2 mm from the vestibule using acrylic resin (Acrostone, England) and wax rims (Cavex set up wax, regular modeling wax, Cavex, The Netherlands, Holland) at a predetermined correct vertical dimension were attached to it. The custom trays were tried in the mouth, checked and corrected for extension, retention and stability.

Closed-mouth impression technique Procedure:

Fixed occlusal rims were fabricated at proper vertical dimension of occlusion to help in maintaining the maxillary and mandibular custom trays in place during border molding and taking the impression. Reference lines such as high lip line, canine lines and midline were marked on the occlusal rims to be scanned and transferred to the software later on.

Tray adhesive was applied and serrations were made over the borders of the modified custom trays to enhance the retention of the silicone border molding material (Speedex, Coltene, Switzerland). Putty consistency silicone material was manipulated and a roll of 3-4 mm width was positioned along the border of the custom trays. The posterior palatal seal area was done according to the arbitrary conventional method. During the custom tray fabrication the posterior vibrating line was arbitrary drawn from on hamular notch to the other on the study cast for accurate posterior extension of the tray. Following the custom tray fabrication the anterior vibrating line was identified with the patient sitting upright with a forward head tilt by palpation using a T-burnisher and both anterior and posterior

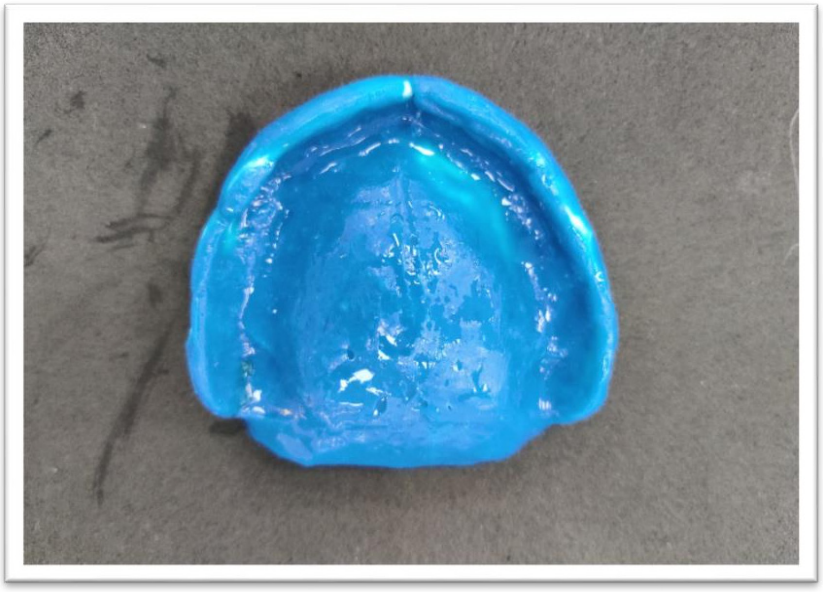

Figure-1 Maxillary Final Impression

vibrating lines were drawn intraorally by an indelible pencil to be transferred to the fitting surface of the final impression. The border molding material was placed on the custom tray in a Cupid's bow shape following the extensions that was determined before. The patient was asked to perform the Valsalva maneuver and short and exaggerated bursts of "ah". The process was done till sufficient retention was obtained.

Maxillary and mandibular custom trays with occlusal rims were then inserted in the patient's mouth and the patient was guided to close at proper vertical dimension of occlusion. The patient was instructed to slowly perform the normal functional movements as swallowing, smiling, yawning, whistling, pressing his lips together and moving his tongue sideways. Border molding is performed

Figure-2 Closed-Mouth Impression Technique

carefully to obtain the functional movement of the muscles. Final wash impression was completed using light consistency silicon material and the patient was asked to perform the active muscle movements with the trays held in place as before. The impression was checked for accuracy, borders extension and surface details **(Figure1)**. The centric occluding relation was cautiously recorded by static method. V-notches were made in the upper occlusal rim and soft wax was used to register the jaw relation record where the upper and lower occlusal rims were secured to each other in centric position, washed, disinfected and scanned **(Figure 2)**.

Grouping of digital denture bases

Group (A): Ten digital denture bases constructed from scanning of final impression and group (B): Ten digital bases constructed from scanning of master casts.

Construction of denture bases obtained from scanning of final impression(Group A)

The 3shape desktop scanner D850 (3Sshape, Denmark) was used for scanning and 3shape Dental System

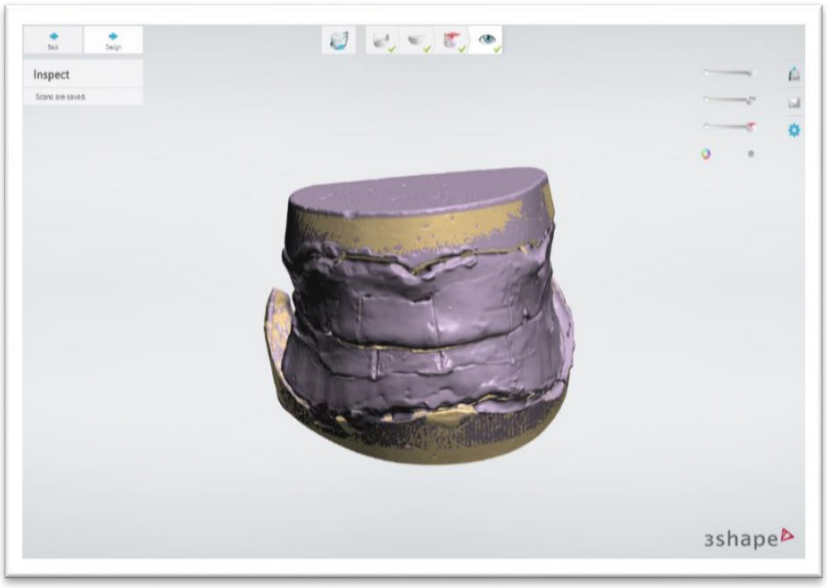

Figure-3 The Virtual Assembly

software (3shape Dental system, Denmark) was used for the designing procedure. The impression was scanned after being sprayed with occlusion/ antiglare spray (okklu- Exact Spray, dent-e-con e.K., Lonsee, Germany).

The closed-mouth impression scanning resembles the triple tray on the software. First step was scanning the maxillary side of the triple tray (maxillary impression), Then the mandibular side of the triple tray (mandibular impression) and lastly the frontal side of the triple tray (the frontal side of the closed-mouth impression/ the jaw relation). Then scanning procedures was carried out till the image appeared on the screen. Next step was trimming the borders to obtain a virtual assembly**(Figure 3)**.

Surveying was done to determine the path of insertion and no blockout was needed. Model analysis was carried out in the following order: determining the occlusal plane then the characteristic

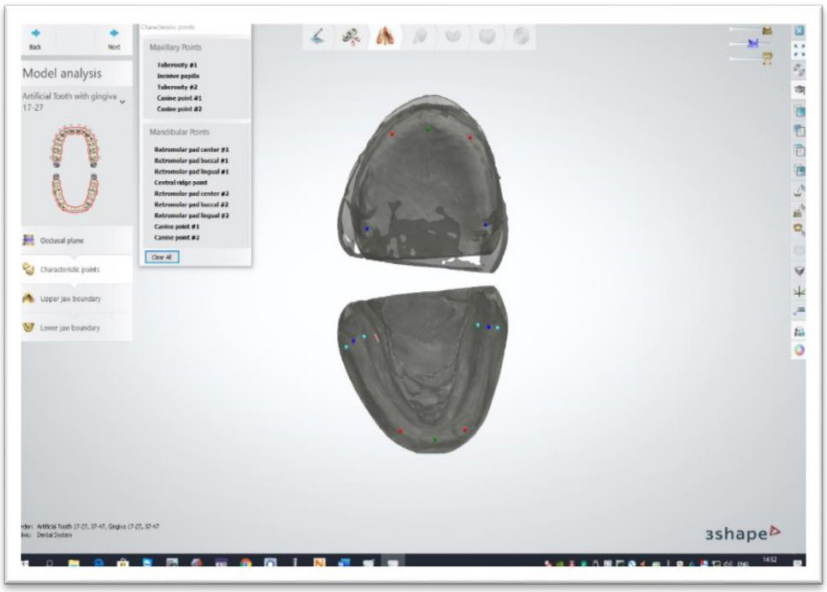

Figure-4 Determining the Characteristic Points on Both Jaws

points were marked on the upper and lower models to locate the incisive papilla, tuberosities, retromolar pad, central ridge point and canine points **(Figure 4)** and finally the jaw boundaries and the depth of the vestibule were marked for proper extension of the denture base for maxillary arch then the mandibular arch respectively and the thickness of denture base was set to 2mm for standardization purposes. Initial

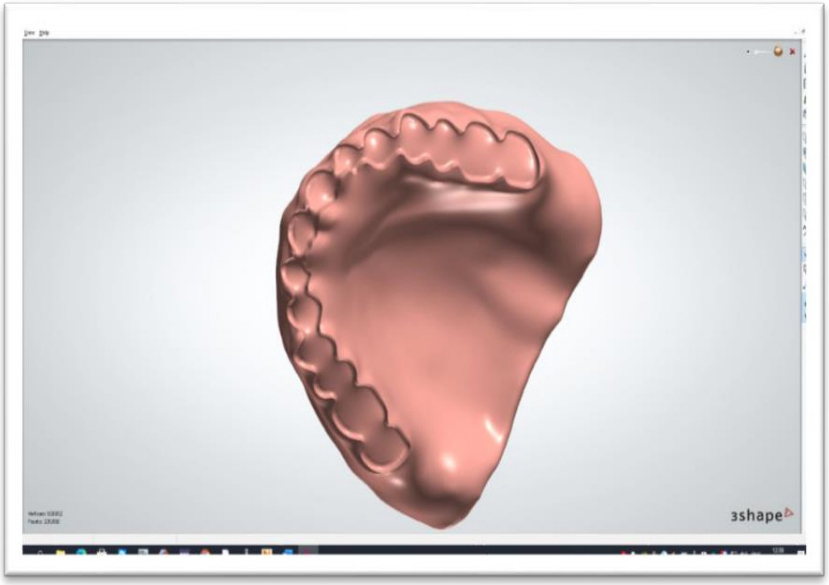

Figure-5 The denture base STL file

setup of artificial teeth was done using an appropriate size of set of teeth from the software library and finally the final design for the upper and lower Dentures were obtained. The Denture was saved in the form of two STL (standard tesselation language) files, one for the denture base and one for the teeth**(Figure 5)**.

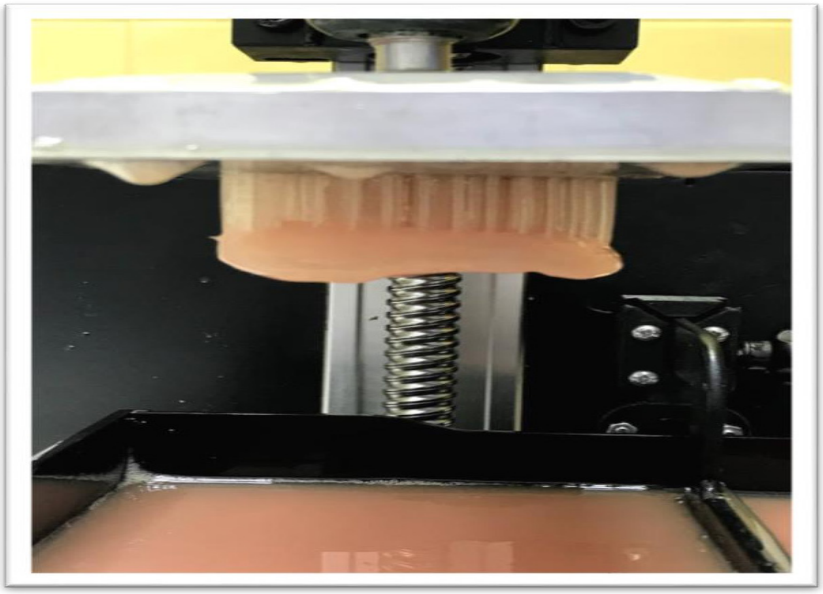

Figure-6 The Denture Immediately After Printing

Construction of denture bases obtained from scanning of master cast (Group B)

After scanning the impression, it was boxed using plaster and pumice technique. then, the maxillary cast was scanned first then the mandibular cast and lastly the jaw relation record. Same procedures was carried out till the final step **(Figure5)**.

STL denture base design files produced from impression scanning and cast scanning were transferred to AutoCAD Autodesk software to determine the geometrical center of the arch then a sphere was created in the center to determine where the wire loop will be fixed.This step is essential for performing the retention test and standardization of the testing procedure. The denture bases were fabricated by

additive manufacturing technique using Dent2 Mogassam (LLC Co. Egypt, Cairo) **(Figure 6)**.

Retention Measurement Test

Each patient was asked to sit comfortably on the dental chair with their head on the head rest and the occlusal plane of the maxillary arch parallel to the floor. The denture base was seated in the mouth and manipulated in a consistent manner with uniform digital pressure until it took a comfortable and accurate position. The base was allowed to reach a stable equilibrium position in relation to the

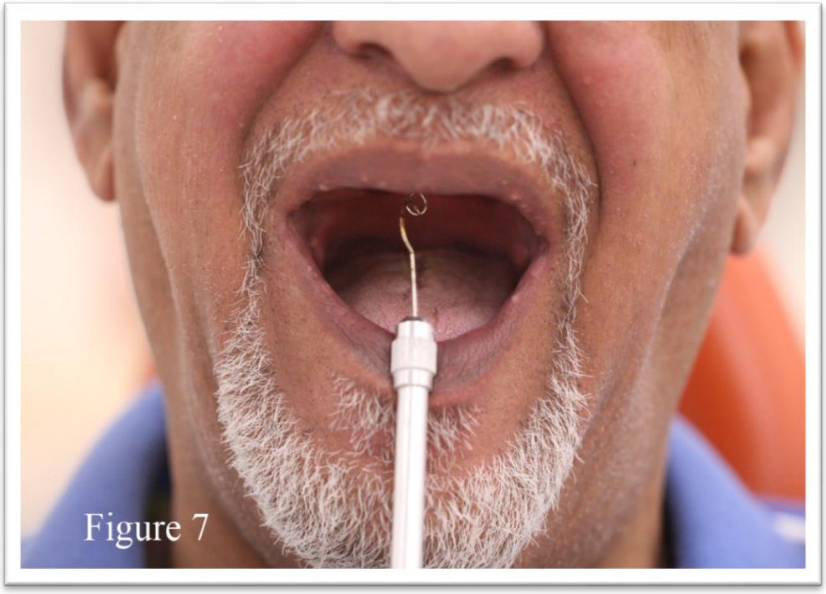

Figure-7 The Direction of Pull is Perpendicular to the Occlusal Plane

palatal mucosa for five minute before beginning of the testing procedure. The hook of the digital push pull gauge (HF-50N Force Gauge) was attached to the wire loop in the denture base and the device started pulling the denture base with the force displayed on the screen. When the denture started losing retention and moved vertically the force was recorded. The test was done three times with five minutes interval in between each test and the readings were recorded for each denture base and the average value was taken **(Figure 7)**. Measurements of both denture bases groups were done at the same session for standardization purposes. After measuring the retention of each denture base the complete denture for each patient was completed conventionally.

Statistical Analysis

Data was analyzed using Statistical Package for social Science software computer program version 23 (SPSS, Inc., Chicago, IL, USA). Data was presented in mean and standard deviation. Student's t-test (Unpaired) was used for comparing data. The significance level was set at $P \leq 0.05$.

Results

Table 1 shows the mean, standard deviation for repeated measures for the retentive values of Data expressed as mean and ±SD

Retention	Impression Scanning group	Cast scanning group	P- Value
MEAN	43.8	41.86	0.4
±SD	±8.5	±7.5	

±SD: standard deviation P: Probability *: significance <0.05

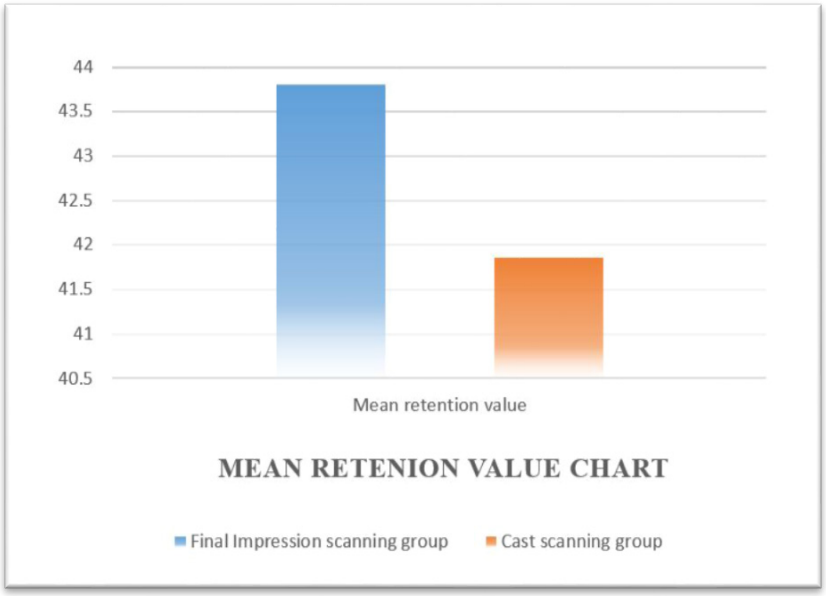

Figure-8 Clustered Column Chart Demonstrating the Mean Retention Values of Both Scanning Groups.

the final impression scanning group and the cast scanning group after being calculated and compared using unpaired student's t-test.

Final Impression scanning group retention measurement mean value was 43.8 and standard deviation of the values was ±8.5, while cast scanning group retention measurement mean value was 41.86 and standard deviation of the values was ±7.5.

The significance level was set at $P \leq 0.05$. The P value of the unpaired student's t-test for this study was 0.4. Although final impression scanning group showed slightly higher retention values than cast scanning group the results revealed that there was no statistically significant difference between the retention of the two digital scanning groups **(Figure 8)**.

Discussion

Retention of complete denture is one of the most important factors determining patient satisfaction. Attempts have been made to improve denture retention such as creating a denture base with the exact replica of the patient's mouth ensuring that the denture base conforms to the underlying mucosa. The patients had no bony or soft tissues undercuts to eliminate the effect of mechanical factors on the retention of the denture bases. Also, patients having severely resorbed maxillary ridge, torus palatinus, V shaped palatal vault and Xerostomia were excluded to avoid their adverse effect on denture base adaptation and retention. Uncooperative patients and those with limited mouth opening or neuromuscular and TMJ disorders were excluded to facilitate the process of intraoral evaluation of denture base retention (7).

In this study, two scanning protocols were used to assess their effect on retention of complete denture. In digital fabrication of complete denture the data acquisition step is very important as it predicts the accuracy and fit of the final denture (8).

Maxillary and mandibular final impressions were made with closed-mouth impression technique along with the jaw relation record. The jaw relation record was taken to provide the data required to design and construct the digital denture bases and to fabricate a conventional complete denture which was delivered to each patient at the end of the study. Merging the maxillary and mandibular final impressions and the jaw relation record into one decreases the inaccuracies that may be caused by imprecise matching of the jaw relation record scan with the impression scan on the software if they were scanned separately. Since the degree of denture base retention depends on the surface tension of the saliva and the intimate fit of the base to the mucosa especially along the periphery thus the posterior palatal seal was recorded by the conventional technique during the border molding procedure. Preserving the final impression borders was crucial in the study. Therefore boxing using plaster and pumice technique was carried out (9–11.)

The master casts were scanned as Group B (cast scanning group) along with the jaw relation records. Before scanning the impressions and jaw relation records were sprayed with titanium oxide spray. The occlusion spray enhanced the surface optical properties of the impression and jaw relation

record. Although the occlusion spray may add a layer of another material to the impression and change its dimensions, the occlusion spray with average particle size of 5μm do not produce any significant effect (12,13).

The step of surveying on the software confirmed the absence of undercuts in the denture bearing area thus there was no need for any blockout that would have adversely affected the results of both adaptation and retention of denture bases in the study. Borders of the denture base were digitally traced on the software for both groups to determine the depth of the vestibule. In both groups the thickness of denture base was set to 2mm for standardization purposes as the denture base thickness is one of the factors affecting its distortion (14).

Choosing the accurate location of the geometric center to preform retention testing is crucial for testing the retention of maxillary complete denture base. In This study the geometric center was determined digitally after the design process for standardization between the two STL files (15-17).

Measurements of both denture bases groups were done at the same session to avoid any changes in the form of the mucosa that occur throughout the day which may affect retention measurement .

The patient was seated upright in the dental chair with his mouth open and lips relaxed in order to avoid losing the peripheral seal. The denture base was inserted in the patient's mouth and allowed to remain for five minutes to ensure its intimate contact with the mucosa before the testing procedure (18,19).

The metallic hook engaged the wire loop in the palatal portion of the denture base and dislodging force was applied. The palate and the maxillary ridge were at nearly 45 degrees to the floor so the applied dislodging force was nearly perpendicular to the denture base. The peak hold option in the device was selected to record the maximum force needed to dislodge the denture base which expresses its retentive value. The testing procedure was carried out three times with five minutes interval between each test for each denture base and the average values were recorded (20,21).

From this study, data revealed that impression scanning group showed slightly higher retention values than cast scanning group. This can be explained by the human errors taking place in the conventional part of the hybrid method of digital denture manufacturing. These errors can present when conventional impressions are boxed and when stone casts are poured. The procedure of boxing of the impression can lead to inaccurate replication of the impression borders which affects the standardization of the process and can affect the resulting denture base intimate contact to mucosal tissue and consequently affecting the denture base retention. Likewise, the dimensional changes involved in the time of pouring the stone casts and the technique itself can lead to inaccurate adaptation of the denture base which results in lower degree of denture base retention.

This dimensional changes although might be insignificant but can occur if the time between taking the impression and pouring it exceeded one hour. In this study, the time elapsed between final setting of the impression material and poring the cast might exceeded one hour after evaluation, disinfection, scanning, boxing and pouring the impression were completed (22) .

Yet, there was no statistically significant difference between the retention of the two scanning groups. This could be due to the lack of processing distortion of the printed denture bases in comparison to conventional method and standardization of the designing and manufacturing process. Moreover, the ability of the extraoral scanner to scan a positive replica of the ridge and oral tissue is almost the same as its ability to scan a negative replica (23,24).

Conclusion

Within the limitation of this study the following can be concluded, both extraoral digital scanning protocols has no effect on the degree of complete denture base retention.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Ethics committee of Ainshams, and approved by the Institutional Review Board Ethics Committee of Ain Shams University (protocol code FDASU-RecIM121810 and date of approval 19\12\2018).

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