Evaluation Of Retention and Assessment of Biting Force Distribution of a Complete Denture Fabricated Using 3D Printed Custom Trays with Arcus Digma Versus Conventional Method (A Cross Over Study)

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Abstract

The purpose: of this study is to evaluate retention and occlusion of complete dentures fabricated using 3D printed custom trays with the aid of arcus digma in less steps versus conventional method.

Material and method: Ten patients were selected to participate in this study. For each one, two complete dentures were constructed, Group I were rehabilitated with a conventional complete denture, while Group II were rehabilitated with a complete denture constructed using 3D designed and printed custom trays with gothic arch tracing of jaw relation with the help of arcus digma.

Results: By comparing the two groups there was a significant difference between them in biting force distribution where (SD) values for biting force difference posteriorly between the right and left posterior segments for centric occlusion was significantly higher for Group I (20.52±7.99) than Group II (14.45±7.33). Anteriorly Group I (27.85±25.68) had significantly higher mean value for biting force distribution than Group II (21.70±23.92). While there was no significant difference between them in retention evaluation where Group II (31.36±2.73) showed higher mean value than Group I (28.95±5.95), yet the difference was not significant.

Conclusion: Within the limitations of this study, it was found that dentures made by using gothic arch technique in taking centric relation by the help of arcus digma was more accurate in occlusion, this means that the force was more evenly distributed on the denture leading to better stability and fewer adjustments. Dentures made using this technique also had retention competent to regular dentures.

Keywords: Bone loss, Distal extension base, Digora, Double OT cap, lower arch.

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**Introduction:**

Removable partial dentures (RPD) continue to be an important prosthetic consideration in many oral reconstructions, particularly when edentulous ridges posterior to a patient's remaining teeth have to be restored. Prosthetic treatment options for partially edentulous patients include basic conventional removable partial dentures, overdentures, removable partial dentures with attachments or dental implants.\(^1\)

Rehabilitation of a partially edentulous arch can be challenging in Kennedy’s class II distal extensions to restore esthetics and function successfully. In such a condition, a fixed partial denture cannot be fabricated due to the absence of a distal abutment an implant-supported prostheses can be planned but they are not always feasible due to insufficient bone and cost considerations. So, in such situation, a casted partial denture is largely preferred. These partial dentures are made retentive by the use of retainers and precision attachments.\(^2\)

In attachment retained unilateral partial denture design, 1\(^{\text{st}}\) and 2\(^{\text{nd}}\) premolars are most often used as abutment teeth. The canine and 1\(^{\text{st}}\) premolar can also be an option. The reasons for this is that the long length saddle acts as the class 1 lever; rigid pole with a fulcrum on one side; such can damage the RPD supporting structures.\(^3\)

Extra-coronal precision attachments are those that are used to improve the stability and retention of removable unilateral distal extension prostheses. Additionally, it delivers better aesthetics, requires less postoperative adjustments, and improves patient comfort and satisfaction. These attachments are resilient, allowing the prosthesis to move freely and transmit destructive forces or stresses away from the abutments to supportive bone and tissue.\(^4\)

OT unilateral attachment systems are castable attachments used for unilateral or implant-supported RPD without the need for cross-arch stabilization from the other side of the arch. These attachments have multiple advantages as they provide lateral stability, superior retention, controlled resiliency, no need for milling, overall functional and economical solutions.\(^3,5\)

Digital intraoral radiographs are useful in cases of radiographic follow up for bone height changes. These devices have the advantages of providing consistent image quality, immediate image viewing, elimination of the darkroom, improved detection, electronic image processing, remote consultation capability, reduced exposure to x-rays, and the elimination of potentially hazardous chemicals.\(^6\)

In direct digital radiography the image is digital so it can be stored on a disc facilitate measurements of bone loss or gain along the root surface, as well as overcoming the limitations of indirectly digitising a film with a camera or scanner. Digora is the cheapest method of assessment and delivers the lowest radiation dose to the patient during exposure.\(^6\)

Hence, this present study was conducted in an attempt to evaluate the effect of using OT unilateral attachments on the bone loss around the posterior abutment in class II distal extension cases in different saddle lengths using the Digora as a digital intraoral radiography.

**Material and methods:**

**Patient selection and grouping**

Fourteen patients were selected to participate in this study from the out-patient clinic of the Prosthodontic Department, Faculty of Dentistry, Ain Shams University.

The selected patients were free from any Anatomical variations like TMJ disorders and systemic disease affecting neuromuscular control e.g., Parkinsonism, epilepsy, Bell’s palsy etc. Only patients with adequate inter-occlusal distance and normal jaw relationship (class I) were included in this study. Patients with four widely
distributed overdenture abutments in the mandibular arch which were successfully treated endodontically, had sufficient alveolar bone support, good periodontal health and no mobility on clinical examination were chosen to prevent denture base movement over rebound tissues to avoid the effect of resiliency of mucosa which could significantly have an effect on the stability of the denture base and as a consequence lead to false recordings during the process of gothic arch tracing.

All participants included in this study were provided with detailed information about the study where they were informed that they will be a part of a study that needs their best co-operation. They all agreed to participate and follow the instructions given to them in the form of a signed consent. All required steps were taken in order to ensure the protection of the security of the patient’s personal information and the patient's health privacy information were taken. All participants were clearly given notice concerning all their rights, legal duties and privacy practices.

For each one of the patients two complete dentures were constructed, group I received a Complete denture by conventional method, while group II received a Complete denture using 3D printed custom trays for secondary impressions with jaw relation taken using arcus digma gothic arch technique.

All prosthetic steps were done by the same prosthodontist to confirm uniformity of all steps.

Designing and printing of trays as well as tracing of jaw relation with the help of arcus digma was done in the digital center, faculty of dentistry, Ain Shams university. Each patient received two complete dentures at the end of the study.

Prosthetic steps

Upper and lower alginate impressions were made for the selected patients and then dental stone was poured to get diagnostic casts. A tentative centric jaw relation record was made, and then mounting of the casts was accomplished on a simple hinge articulator in order to evaluate their inter-arch distance and interridge relationship.

Abutment teeth were reduced in height to about 1-2 mm above the attached gingiva and contoured to a dome shaped preparation with 15 degrees angulation mesially, distally and lingually and 30 degrees buccally. All line angles were rounded and smoothed. The crest of the dome shape was prepared over the long axis of the tooth. Stannous fluoride gel was applied to the prepared surface. Removal of 2ml of gutta percha from the root canals by gates size 2 was done and after cleaning them from any debris self-etch bond was added then the cavity was filled by flowable composite then cured with light cure.

A) Conventional method

For group I maxillary and mandibular primary impressions were obtained in correctly selected and properly modified stock trays with the use of compound cakes impression material (Pyrax compound cakes, in Roorkee, Uttarakhand (India)) and afterwards they were poured in with dental stone to get upper and lower diagnostic casts. Self-cure acrylic resin special custom trays were constructed over the obtained diagnostic casts. The depth of the vestibule was marked and the tray borders were then trimmed about 2-3 mm shorter. Adhesive material was subsequently applied to the tray, then border tracing and the final wash was performed with the use of medium consistency polyether impression material (Elite Soft Medium Body – zhermack). maxillary and mandibular secondary impressions were then poured in
with dental stone to get upper and lower master casts. Upper and lower occlusion blocks were fabricated on the master casts. Face bow record was taken to help mount the maxillary cast on a semi-adjustable articulator (Semi-adjustable articulator Kavo protar). The lower cast was mounted by centric occluding relation recorded following the interocclusal wax wafer technique.

Protrusive record was made with other occlusion blocks to adjust the articulator horizontal condylar guidance. Right and left lateral records were taken using the check bite method with another two occlusion blocks for each. Records were transferred to a semi-adjustable articulator. Setting was done to provide bilateral balanced occlusion.

A trial complete denture was fabricated, proper seating of the denture was confirmed during the try in stage then delivered to the patient after making the needed adjustments.

The upper and lower waxed up dentures were flasked, wax elimination was done, application of separating medium was performed, packing of heat cured acrylic resin was accomplished, then the flask was closed, and curing was done using long curing cycle. After deflasking, laboratory remount was carried out before finishing and polishing the dentures.

The patients were instructed to perform oral and denture hygiene. The patients were instructed to take the denture out of the mouth for at least 8 hours every 24 hours during sleep and placed in a container containing tap water. The patients were instructed also to brush the prosthesis and abutment teeth after each meal.

B) Digitally augmented steps:
For group II Upper and lower primary impressions (Fig.1) were taken by using intra oral 3D scanner (CEREC Omnicam) digital impression technique directly from the patient mouth to scan the upper and lower arch because it significantly decreases the required time needed for laboratory and clinical work, and the effort and material needed to make plaster casts. It significantly reduces patient discomfort on comparison with traditional physical impression technique. It eliminates the need for impression materials and trays, that are usually very uncomfortable for the patient, in addition patients with strong gag reflex will comfortably use it. In fact, as reported by literature, most patients favor optical impressions to conventional impressions.

In addition, by using this technique we can obtain more accurate custom trays to fabricate definitive impression precisely. So a technique was developed to merge the intraoral scanning and the printing to make a custom tray and omit the need for primary impression.

All intraoral cameras record individual images or videos by light projection. They are then compiled using the software after the POI (points of interest) are recognized. Evaluation of the first two coordinates (x and y) of each point on the image is done and depending on the distance to the object the calculation of the third coordinate (z) is performed according to the technologies related to each camera. The time needed for a full arch scan was 15 min.

The lips were retracted with a cheek holder and saliva was constantly removed with an aspirator during intraoral scanning by “zig-zag” scanning technique with the help of round parts of composite (3M-ESPE) widely distributed in a fixed positions with occlusion sprays (Occlutec) that act as a reference help the scanner to catch the image and make the surface dry to avoid glossy surface, so it overcome the limitation of scanner during scanning.

Silicone putty impression material was polymerized while maintaining the vertical dimension between the upper and
lower jaws. The polymerized silicone putty was used as a jig after being cut to a relative thickness of around 15 mm.

The silicon jig was positioned between the jaws and it was scanned along with the maxillary and mandibular arch. The standard tessellation language data of the maxillary and mandibular jaws and jig was imported to obtain a jaw relation record to aid in the editing and trimming of the data of the primary impression. Exocad 2.2 valletta software was used to help design as well as create the supporting system for the construction of the custom trays (CAD/CAM trays) utilizing a rapid prototyping system, Additive layering technique, where 3D printing custom tray were printed by the use of a special resin material (EPAX 3D printed resin) (Fig.2).

![Fig. (1): Intra oral scanning of upper and lower arch](image1)

![Fig. (2): Upper and Lower printed custom trays by additive layering technique](image2)

CAD/CAM trays were used to make the definitive secondary impressions for the maxillary and mandibular jaws. Adhesive material (Zhermack universal tray adhesive) (Fig.3) was applied to the tray, then border tracing and the final impression wash were done using medium consistency polyether impression material (Elite Soft Medium Body – Zhermack).

![Fig. (3): Upper and Lower secondary impression with printed custom trays](image3)

The occlusal plane orientation, as well as the lip fullness and appearance were determined by evaluating the occlusion blocks.

The mandibular Gothic arch guiding plate and the tracing screw were assembled (Fig.4). The entire appliance was put into the patient’s mouth and the tracing screw height was adjusted according to the vertical dimension that was previously recorded, then the lower wax rim was reduced to provide a space for the injection of bite registration material.

![Fig. (4): Pin in upper, Plate in lower the height of the tracing screw was adjusted to the previously recorded vertical dimension for recording centric relation using gothic arch tracing](image4)

The patient was educated about the device and the required instructions that were needed to be followed. The components of arcus digma were placed in the patient. The upper face bow was secured to the upper arch. The lower facebow was secured to the lower arch using the Para occlusal clutch prepared earlier (Fig.5). Facebow orientation was adjusted as
described earlier with patient setting upright (90 degrees). Diagnostic module was used, the facebow record was first taken while the patient stays still using the arcus digma to determine the spatial orientation of the maxilla on the software. Recording the centric relation was done by using Gothic arch (most accurate). The patient was asked to slowly perform lateral and anteroposterior mandibular movements while the maxillary and mandibular custom trays were in contact. Then the patient was asked to repeat the previous movements to obtain the mandibular movement tracings showed on the screen.

Fig. (5): Placement of the arcus components in the patient face.

The patient was then asked to move his mandible to reach the exact position at the point mark of the movement trails where the metal tracing screw was previously located to make sure that the mandibular tracings were clear. The occlusal registration material (CharmFlex® Bite) was injected between the upper and lower custom trays. After the two custom trays were properly fixed, it was removed and was sent to the laboratory. Upper and lower secondary impressions were then poured using dental stone to get upper and lower master casts. Mounting of upper cast was done using maxillary (KTS) biting fork that was taken from the patient placed on digma mounting table that was placed on the articulator.

The multiple advances offered by the KaVo Transfer System (KTS) include the axial system, along with the special transfer status which easily permits the quick and smooth transfer of the models to the KaVo PROTAR articulator. This method prevents a lot of the possible transmission errors. The axis does not need to be determined because the articulator axis of the PROTAR is used as the axis system. For the setting of the calculations of the articulator, the bite fork stands in a known relationship with the articulator joints whose settings were calculated.. (13)

Subsequently the centric relation record that was taken using bite registration material was placed on the upper occlusion block, then the lower master cast was attached and mounted into the lower member of the articulator. Transfer angles were taken to adjust and register values of the right and left condylar path inclination (protrusive record), and left and right Bennett angle (right and left laterotrusive records), on the joint mechanism of the dental articulator. Setting was done to provide bilateral balanced occlusion. Try in, delivery and lab remount with denture construction same as in group I.

**Retention evaluation**

In order to evaluate the maxillary denture retention, the geometrical center of the maxillary arch was located and chosen as the measurement point. The exact center of the maxillary denture was marked on the definitive cast by locating the exact center of the incisive papilla and the hamular notches. Then, the distance halfway between points b and c was measured and the point was marked on the denture base posterior border (point D). Finally, half the distance between point a and d was marked as the center of the denture (point E). Self cured acrylic resin was used to attach a stainless-steel hook at the predetermined position of the geometric center, to the outer surface of the denture. The retention of the denture was recorded by the use of a digital force gauge (Digital Push Pull Gauge Force Gauge HF-100N) (Fig.6).
The device was prepared. Then, the unit of measurement was chosen in Newtons and the peak hold option was selected. The desired adapter tension hook was attached to the sensing head. Before each measurement the display was calibrated to zero using the zero button. The denture was inserted in the patient’s mouth and allowed to remain for settling time of 10 minutes before the stainless-steel hook was engaged. The patient was seated in the dental chair in an upright position with his lips relaxed and his mouth opened. In this position the palate and the maxillary ridge were set to a position nearly parallel to the floor. Therefore, the dislodging force that was applied was set to be almost perpendicular to the denture.

This dislodging force was repeatedly applied to the denture base hook until it was ultimately forced out of its position. Retention force was considered as the maximum force needed to completely dislodge the denture. This measuring procedure was consequently repeated five times at an interval of ten minutes for each denture base then recording of the average value was performed. Retention measurements were done at the same time of the day for all the patients.

The key component is the sensor. On biting on the sensor, the resultant change in electric resistance is directly converted into an image on the screen. The program can be operated on two modes force analysis and time analysis.

The width of the maxillary central incisor of each subject was measured by a periodontal probe. The sensor was placed in the patient’s mouth, with the sensor support pointer between the two central incisors and the handle was kept as parallel to the occlusal plane as possible. The patient was asked to close, and the tooth contact was observed on the screen. The patient was instructed to bite down normally on the sensor for 2 seconds and then opened slowly.

When recording was completed, the Realtime window turns into a 2-D Movie window, that was divided into two equal-colored boxes (one green for the left side and one red for the right side) around the mid-sagittal plane showing the difference between the intensity of the biting forces on both sides. A 3-D Movie window, Graph window and Graph Zoom window were also automatically opened for the current movie. The Graph and Graph Zoom windows contain color-coded “traces” representing the forces applied on each tooth, the magnitude of forces applied, the distribution of the forces along the arch and teeth under heavy contact and premature contact inside each of the colored boxes in the 2-D Movie window. The same process was done to estimate contact at protrusive and lateral eccentric. Each movement was repeated thrice and the average of three recordings were taken.

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

Numerical data were presented as mean and standard deviation values and were analyzed for normality using Shapiro-Wilk
test. Biting force data showed non-parametric distribution so they were analyzed using Mann-Whitney U test, while retention data showed parametric distribution, so they were analyzed using independent t-test. The significance level was set at $p \leq 0.05$ within all tests. Statistical analysis was performed with R statistical analysis software version 4.1.2 for Windows.

**Results:**

The digital force gauge was used to assess retention of the maxillary denture that revealed after statistical analysis that Gothic arch group showed higher mean value than conventional group but there was no significant difference between the two groups in retention evaluation (Table 1).

| Retention (Mean=SD) | p-value |
|---------------------|---------|
| Conventional        | 20.95±9.95 | 31.36±2.73 | 0.178ns |

*, significant ($p \leq 0.05$); ns, non-significant ($p>0.05$)

T-scan was used to assess occlusion of both dentures. On comparing the occlusal force ratio for right and left, between group I and group II, which are described as (100 percent represented by 1.0). The test revealed after statistical analysis that there was a significant difference between the two groups in occlusal analysis where mean and Standard deviation (SD) values for biting force difference between the right and left posterior segments for centric occlusion in the conventional group showed significantly higher value than gothic arch group which indicates that the biting force was more equally distributed both side in the gothic arch group. This group required only a slight occlusal adjustment while conventional group need more occlusal adjustment. Anteriorly conventional group had significantly higher mean value than gothic arch group indicating more unfavorable contact anteriorly that needed more occlusal adjustment to achieve no contact anteriorly to avoid instability of the denture (Table 2).

Conventional group rendered a less favorable biting force distribution to reach for the optimum occlusion than gothic arch group and statistical analysis of the digital measurements confirmed these findings.

| Biting force distribution difference posteriorly for centric occlusion (Mean=SD) | p-value |
|-----------------------------|---------|
| Conventional                | 20.52±2.99 | 14.45±2.33 | 0.002* |

*, significant ($p \leq 0.05$); ns, non-significant ($p>0.05$)

**Discussion**

The benefits resulting from application of this procedure were multiple. The use of 3D printed custom trays helps in the matching of the anatomic structures more accurately for the fabrication of the definitive impression. So this technique was developed to merge the intraoral scanning and the printing to make a custom tray and omit the need for a conventional primary impression.(19)

The process of impression digitalization for CDs makes the communication of intraoral information directly to the technician after performing the scan much easier, the prosthodontist can e-mail the images to the dental laboratory, where its accuracy can be immediately checked by the technician. If for any reason the dental technician is not fully satisfied with the observed quality of the optical impression he received, the prosthodontist can feasibly perform another scan without the loss of any material or time and without the need to recall the patient to attend for a second appointment. This specific aspect truly strengthens and simplifies the
communication process between the prosthodontist and the dental technician.(20–22)

The technique used in this study aims to simplify the assembly of the Gothic arch tracing method by the use of a digital face bow (ARCUS digma), resulting in a more convenient and applicable centric relation recording. ARCUS digma system was chosen for its ability to accurately reproduce the inherent condylar guidance as well as the locational relationship between the maxilla and mandible in patients where results obtained for the final prosthesis were exceptionally satisfactory as evaluated by T-scan. These superior results could be attributed to the fact that the lower jaw can move freely in relation to the upper jaw without performing any type of occlusal interaction. This excludes the influence of operator and occlusal interference on TMJ kinematics. It can obtain a 3D representation of the real surfaces at real time of its movement which consequently leads to better recording and reproduction of harmonious occlusal contacts in the final prosthesis.(23) Since digital networking information is more accurate, quality controlled complete dentures can be delivered to the patients with more predictable results than the conventional technique. The digitalization of the process of the fabrication of CD permits simplification of the regular complicated treatment and tedious laboratory processes which is required for the conventional method.(19)

Hence, this study was conducted to assess the retention and the occlusion of both dentures constructed using 3D printed custom trays after scanning both jaws with intra oral scanner. It simplifies centric relation recording using gothic arch technique by the help of arcus digma after combining it with definitive impression in a single step.

The digital force gauge was used to assess retention of the denture that revealed after statistical analysis that Group II showed higher mean value than Group I but there was no significant difference between the two groups in retention evaluation but less effort, time, materials and revealed to be more satisfactory to the patient.

T-scan was used to assess occlusion of both dentures as it has the advantage of not only being able to record occlusal contacts but also being able to analyze their timing and force distribution level with high precision (100%) that revealed after statistical analysis that there was a significant difference between the two groups in occlusal analysis where mean and Standard deviation (SD) values for biting force difference posteriorly for centric occlusion were Group I showed significantly higher value than Group II which indicate that biting force was distributed more equally on both sides in Group II leading to better stability and fewer adjustments needed. Anteriorly Group I showed significantly higher mean value than Group II that need more occlusal adjustment to achieve no contact anteriorly to avoid instability of the denture.

The digital measurements confirmed this finding and the validity and accuracy of ARCUS digma system was confirmed. The process of centering the occlusal force in complete dentures leads to the favorable directing of forces to help eliminate side to side unbalanced prosthesis torquing. These desirable end-results on prosthesis insertion was validated by the utilizing of the accurate data acquisition along with the occlusal force display features incorporated in the T-Scan III computerized occlusal analysis system. The prosthodontist can readily observe the exact location and distribution of occlusal force as well as the specific occlusal adjustments needed to attain a properly centered, measurably balanced
biting force distribution. This is attained by the help of a full closure force movie recording, the COF occlusal force summation analysis and the force versus time graph. (24)

This balanced force distribution significantly improves the basal tissue seat supporting the denture by insuring that, while the denture is being loaded during mastication, it is properly seated by the occlusal force summation falling equally onto the broadest and the most supportive available tissue. (24)

Therefore, analysis of the data indicates that some clinical or laboratory steps can be skipped, which saves clinical time and reduces costs without prejudicing the prosthesis. Dental schools should consider these findings when designing complete denture courses.

Conclusion

Within the limitations of this study, it was found that dentures made by using gothic arch technique in taking centric relation by the help of arcus digma was more accurate in occlusion, this means that the force was more evenly distributed on the denture leading to better stability and fewer adjustments. Dentures made using this technique also had retention competent to regular dentures.

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