EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 68, 1685:1693, APRIL, 2022
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
FIXED PROSTHODONTICS AND DENTAL MATERIALS
Submit Date : 2022-01-25 • Accept Date : 2022-02-10 • Available online: 2022-03-30 • DOI : 10.21608/edj.2022.118307.1965

EFFECT OF DIGITAL AND CONVENTIONAL WORKFLOWS ON COMPLETE DENTURE RETENTION

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ABSTRACT

Introduction: CAD/CAM complete dentures were expected to provide better retention than conventional dentures, the current work tested the retention of complete dentures manufactured by conventional and/or digital workflows using a clinical direct pull-out of the maxillary complete dentures.

Materials and methods: Ten completely edentulous male patients participated in this study, each patient was provided with 3 dentures, a denture made with conventional techniques, then a denture made with combined conventional/digital techniques, and finally a denture made with digital techniques. Each denture was used for a period of one month, and at the end of the month, a denture pull-out retention test was conducted and the retentive forces of dentures in each group were collected, tabulated and statistically analyzed.

Results: Dentures made with combined conventional/digital techniques had more retention than dentures made with conventional techniques, and both had more retention than dentures made with digital techniques.

Conclusion: Combination of the conventional and digital workflows produced maxillary dentures with higher retention than those produced from conventional or digital workflows alone.

KEYWORDS: CAD/CAM dentures, complete dentures, retention, optical impression.

INTRODUCTION

Computer aided design and computer aided manufacturing (CAD/CAM) of complete dentures was expected to overcome problems associated with conventional complete dentures,[1,2] but inadequate retention, esthetics and patient dissatisfaction were reported with CAD/CAM dentures.[3] However, other studies claimed that CAD/CAM dentures had an improved fit and better retention, together with other advantages such as reduced dental chair time, less number of visits, and superior mechanical and physical properties of the pre-polymerized polymethyl methacrylate (PMMA) disks used for the milling of these dentures.[4,5]

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The CAD/CAM dentures complete digital workflow still suffer from the inability of digital impressions to exert peripheral selective pressure with the currently available intra-oral scanning technology,[6] a situation which suggested combination of conventional techniques and CAD/CAM technology to obtain clinically acceptable results and overcome disadvantages of different CAD/CAM systems.[7,8]

Direct comparisons of milled CAD/CAM dentures to 3D printed, injection molding, and compression molding complete dentures revealed that the CAD/CAM milling produced dentures with better fit and fewer dimensional changes which increased the frictional retention and stability, and improved its clinical performance.[9-13] However these claims needed to be tested against the conventional concepts, of selective impression techniques and properly extended dentures borders,[14,15] with a direct mechanical pull-out test of the dentures from the patients mouth to actually assess the amount of retention provided by each category.[16-23]

Together with the limitations of digital direct intra-oral optical impressions, another challenging procedure to the full digital work flow of complete dentures was the registration of jaw relationships, which is not currently available in any CAD/CAM system, and therefore suggested extra-oral digitization of the conventional record blocks to establish the horizontal and vertical edentulous jaws relationships,[24-36] and work in concert with the available CAD/CAM technology to provide the better clinical outcomes,[37] that are not yet able to benefit from the newly introduced technologies for analysis of mandibular movement and computer assisted registration of condylar movement of dentulous patients.[38,39]

Based on the previously presented data, the current work aimed at testing the retention of complete dentures manufactured by conventional and/or digital work flows using a clinical direct pull-out test of the maxillary complete dentures.

MATERIALS AND METHODS

The current work included 10 completely edentulous male patients, ranging from to 50 to 70 years old, who signed an informed consent after understanding and approving the research design, their inclusion criteria were as follows: 1) Completely edentulous upper and lower arches, 2) Average size edentulous arches covered by normal mucosa, 3) Edentulous arches with minimal resorption. Patients' exclusion criteria were as follows: 1) Extremely large or extremely small edentulous arches, 2) Edentulous arches with severe unilateral or bilateral bony undercuts, 3) Oral mucosa exhibiting undercuts or redundancy or pathologic changes, 4) Fibrous, flat or severely resorbed ridges, 5) Papillary hyperplasia, 6) Poor neuromuscular control, 7) Diabetes and/or any bone affecting disease. Each patient was provided with 3 dentures, a denture made with conventional techniques, then a denture made with combined conventional/digital techniques, and finally a denture made with digital techniques. Each denture was used for a period of one month, and at the end of that month, a denture retention test was conducted to evaluate its retention.

Conventional workflow

First the patients were provided with dentures made using conventional procedures and processing, where each patient had a primary impression, selective pressure secondary or final impression, as seen in figure 1, which were made by peripheral molding of the individual trays using green compound sticks (manufactured by Spofa Dental, Czech Republic, for Kerr corporation, USA) with working temperature 50-51°C, and Zinc-Oxide eugenol impression material (Cavex Outline, Cavex Holland BV), these impressions were poured into type III hard dental stone (Model Hard Stone, ENRST HIRNICHS Dental GmbH, Germany). After fabrication of the record blocks, registration of jaw relationships and verification of centric relationship

were conducted as seen in figure 2, followed by try-in, and delivery of a denture that was processed using conventional compression molding of the heat cured PMMA (Vertex SR, Vertex Dental, Zeist, Netherland), these dentures represented group I. After one month of use, group I maxillary complete dentures retention were tested using a pull-out test as seen in figure 3, where a stainless steel loop was secured in the middle of the maxillary dentures palatal region with self-cured acrylic resin, and a force meter (FG-5000A, Force Gauge, MRC LTD) was attached to the hook and pulled out the dentures from the patients mouths, with the force meter being perpendicular to the dentures as the patients were in supine position and the dentures occlusal plane was perpendicular to the floor. The device was adjusted to display the readings in grams of weight and the dentures retentive forces were registered.

Conventional/digital workflow

Second, while making group I dentures, optical scans of the master models and their jaw relationships record blocks were made using Kavo bench top scanner (Kavo ARCTICA AutoScan) and were saved as standard tessellation language (STL) files, these digital records were used to design the complete dentures by the Apex Exocad program, where the digital casts generated from the master models scans were oriented using the jaw relationships scans, and the Apex software was

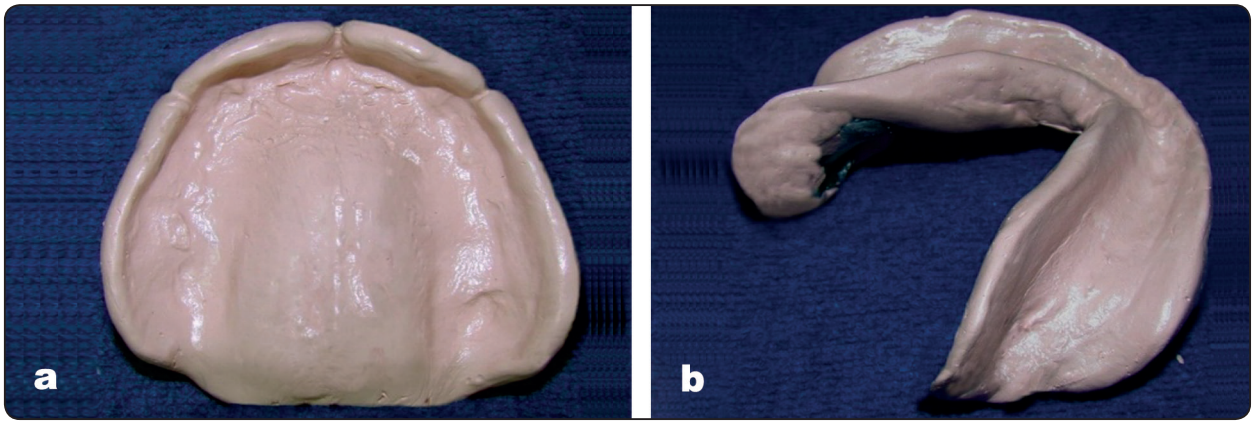

Fig. (1): Secondary impression: (a) maxillary impression, (b) mandibular impression.

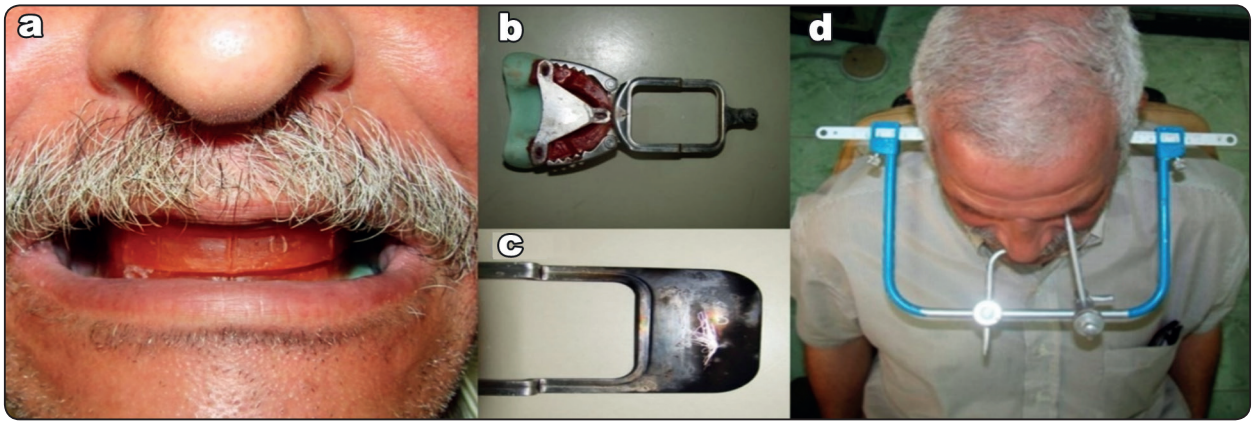

Fig. (2): Jaw relationships and verification of centric relationship: (a) registration of vertical and horizontal jaw relationships, (b) attaching extra-oral Gothic arch tracer to the record blocks, (c) coordination with the Gothic arch tracer arrow head with the registered centric relationship, (d) registration of the orientation relationship using the face-bow transfer.

used to determine the peripheral limiting structures of the denture bases as seen in figure 4a, and set the artificial teeth as seen in figure 4b, this design was then used to produce dentures of group II by the open source CAD/CAM (Vita Vionic; Vita Zahnfabrik, Germany) milling of complete dentures disks (Vita Vionic Base; Vita Zahnfabrik, Germany) as seen in figure 4. The group I dentures were taken from the patients who were provided with group II dentures, and after one month of use, group II maxillary complete dentures were pulled out from the patients' mouths, in the same manner as for group I dentures, and their retentive forces were registered.

Digital workflow

Third, a digital optical impression, which was purely mucostatic, using CEREC Omnicam (Sirona dental Systems GmbH, Germany), was made for each patient as seen in figures 5, where the tongue, cheeks and lips were retracted properly and the intra-oral scanning process conducted in an in-and-out zigzag motion starting from the left maxillary tuberosity, then proceeding from the buccal sulcus across the edentulous ridge to the hard palate, then going back to the buccal sulcus again all around the edentulous arch, similarly in the lower arch the same scanning technique was used, starting from the left retro-molar pad and going around the edentulous arch from the buccal to the lingual sulcus in one continuous scanning motion, then the upper and lower impressions were saved in STL format. Together with each patient digital impressions STL files, an STL file of the scan of his corresponding jaw relationship record blocks, that was used to make group I denture, were used to make group III dentures that were produced by CAD/CAM milling of complete dentures disks as for group II. The group II dentures were taken from the patients who were provided with group III dentures, and after one month of use, group III maxillary complete dentures were pulled out from the patients' mouths, in the same manner as for group I and II dentures, and their retentive forces were registered.

Finally, the retentive forces of dentures in each group were collected, tabulated and statistically analyzed using the analysis of variance (One-Way ANOVA Calculator, including post Hoc Tukey HSD), the results were designated as statistically significant at $p \leq 0.05$

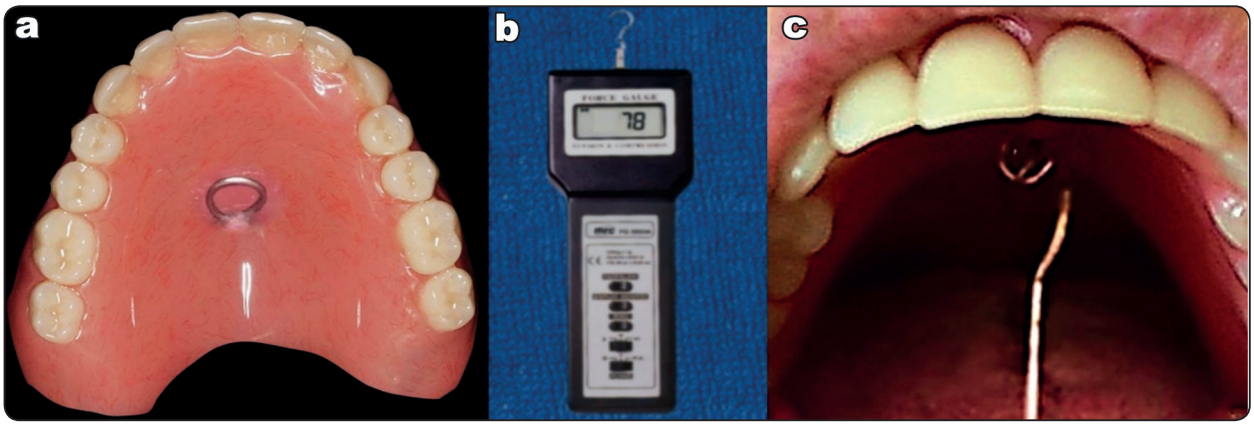

Fig. (3): Maxillary complete dentures retention test using pull-out, (a) the stainless-steel loop attached to the compete denture palate, (b) the Force Gauge used; note that an extension piece was used lengthen the pull-out arm so that the device reached the loop easily, (c) the denture pulled out from the patient mouth to test its retention.

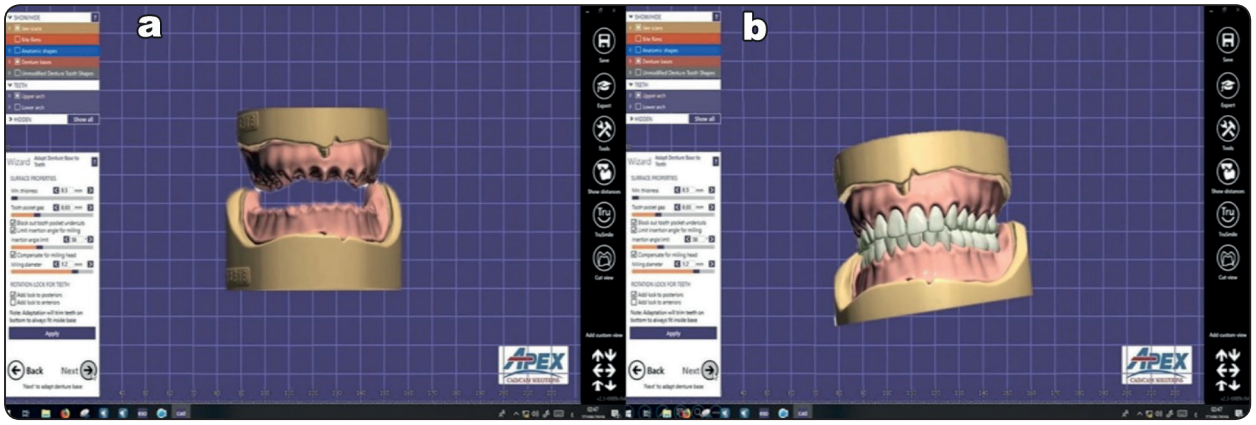

Fig. (4): CAD/CAM design of complete dentures, (a) Determination of denture base peripheral outline and teeth sockets, (b) Arrangement of teeth.

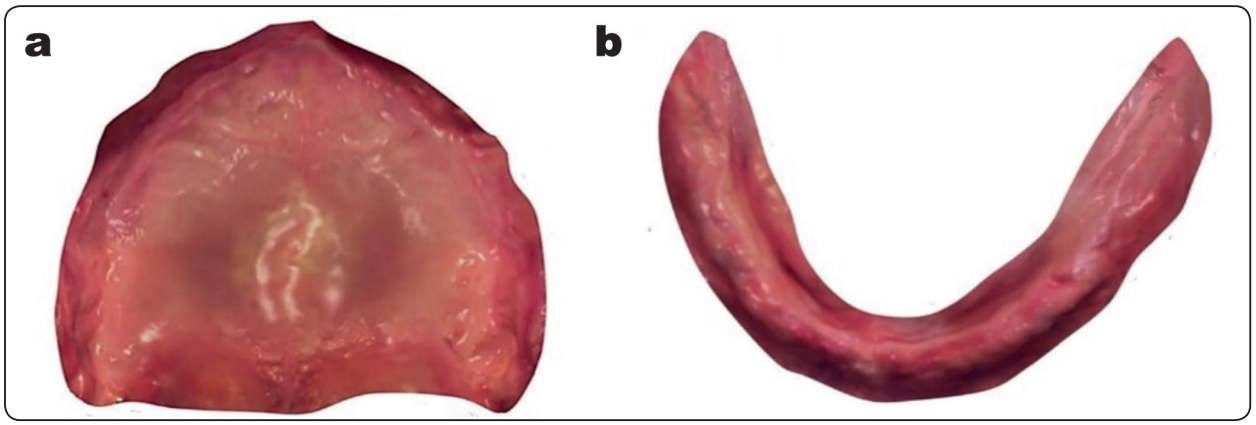

Fig. (5): The optical impression used in group III, (a) maxillary optical impression, (b) mandibular optical impression.

RESULTS

Figure 6 shows the distribution of the weight needed to dislodge the maxillary dentures of the different studied groups. Table 1 shows that the mean weight needed to dislodge the maxillary dentures of group II is greater than that of group I, and that the mean weight needed to dislodge the maxillary dentures of group I is greater than that of group III. Table 2 shows comparisons between the studied groups where the difference between groups I and II, groups I and III, and groups II and III were statistically significant.

TABLE (1): Descriptive statistics: weight, in grams, needed to dislodge maxillary dentures of each group.

Denture number	Group I	Group II	Group III
1	203	304	89
2	241	268	72
3	233	265	112
4	224	257	96
5	207	246	139
6	212	249	151
7	221	352	119
8	197	288	116
9	186	243	103
10	179	234	92
Mean	M_1=210.3	M_2=270.6	M_3=108.9
Standard deviation	19.92	35.65	23.76

TABLE (2): Statistical analysis: pairwise comparisons of the studied groups,

Pairwise Comparisons		HSD $_{.05}$=30.2532 HSD $_{.01}$= 38.7811	$Q_{.05}$=3.5064 $Q_{.01}$=4.4948
Group I versus Group II	M_1=210.30 M_2=270.60	60.30	Q = 6.99 (p = 0.0001)
Group I versus group III	M_1=210.30 M_3=108.90	101.40	Q = 11.75 (p = 0.0000)
Group II versus Group III	M_2=270.60 M_3=108.90	161.70	Q = 18.74 (p = 0.0000)

p is statistically significant at ≥ 0.05

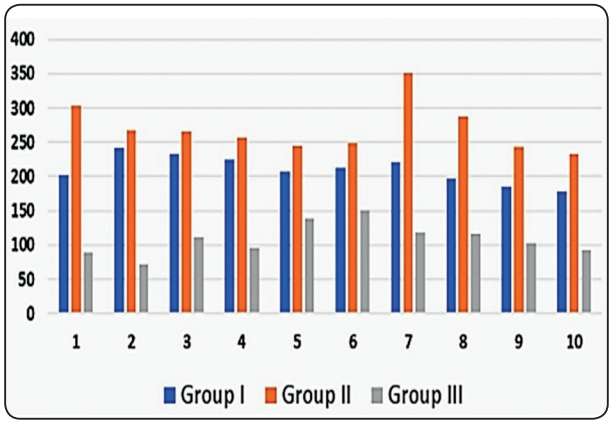

Fig. (6): Weight, in grams, needed to dislodge maxillary dentures of each group.

DISCUSSION

According to de Mendonça et al[1] CAD/CAM dentures workflow could overcome the conventional dentures steps that would lead to complications, Janeva et al[2,4] confirmed this claim and added that digital dentures had a smaller number of visits with significantly higher retention than conventional dentures, Steinmassl et al[5] suggested that the increase in digital denture retention was due to its better fit to the underlying tissues as compared to conventional dentures. However, inadequate retention of digital dentures was reported by Kattadiyil et al[3] as one of its complications that was thought to be due to the inability of optical impressions to perform peripheral seal selective pressure as advocated by D'Arienzo et al.[6] Nevertheless, the full digital workflow of complete dentures was demonstrated by several other studies to yield better dentures than the conventional workflow due to its milling of pre-polymerized polymethyl methacrylate (PMMA) CAD/CAM disks that resulted in better frictional retention, overall accuracy, and homogeneous distribution of adaptation as found by Ali and Al-Harbi [9], Lee et al[11], and Masri et al.[13]

Based on the previously presented conflicting data, this study evaluated the retention of maxillary dentures produced by conventional, conventional/digital, and digital workflows using a pull-out test that was used in several other studies such as those of Sanaye et al,[14] Georgieva et al,[16] Goodacre et al,[17] and AlHelal et al[18] after one months of denture use to allow for denture settling and development of the required neuromuscular control by the patients as advocated by Kabeel and Kholief.[19] This study also used an open CAD CAM system, the Vita Vionic, which accepted scans from non-system specific scanners, and was compatible with the Cermaill Motion 2 CAD/CAM machine.

The results of this study found that the retention of conventionally produced complete dentures was significantly higher than those produced by digital workflow, this finding came in contrast to the findings of AlHelal et al,[18] Kabeel and Kholief, [19] and Faty et al[20] who reported better retention for digital dentures.

The results of this study also found that combining the conventional and digital workflows resulted in dentures with better retention than those produced by convention and digital workflows on separate basis, this could be explained by the fact that CAD/CAM denture bases exhibited fewer dimensional changes as reported by Eldahmy et al,[22] and by the suggestion of Srinivasan et al[28] and Yüzbaşioğlu et al[29] that better dentures could be produced using conventional impressions to ensure best possible peripheral seal, and using the PMMA CAD/CAM disks to eliminate the inherited polymerization shrinkage of the compression molding conventional processing technique. An additional advantage of combining conventional and digital workflows was also overcoming the difficulties of digital registration of jaw relations for completely edentulous patients by scanning of the conventional jaw relationships records as used in this study and as confirmed by Bonnet et al[25] who reported inaccuracies in the finalization of complete denture digital mounting. Another study reporting problems of full digital workflows of complete dentures was that of Venezia et al[27] who found it difficult to record the inter-arch relationships digitally, and challenging for the currently available intra-oral scanners (IOS) to scan the large edentulous arches.

In contrast to the findings of this study, Jung et al[32] did not find any difference in the denture supporting areas between digital and conventional impressions, however, D'Arienzo et al,[30,36] Fang et al,[31] Hack et al,[33]and Alkhodary[35] found that digital impressions of the edentulous patients were not able to selectively press the denture stress bearing areas, or exert peripheral pressure or register the functional depth of the sulcus, instead, and as used in this study, indirect digitization of conventional final impressions or master casts was found to provide digital impressions STL files with the needed functional form of the edentulous ridges and its sulci as reported by Kontis et al.[34]

In conclusions, the findings of this study confirmed the suggestions of Jurado et al[7] and Villias et al[37] that combination of the conventional clinical techniques and the CAD/CAM technologies could provide clinical results that overcome the disadvantages of either the conventional and digital workflows, however, it is important to consider the limitations of the current study which used only one CAD/CAM system, and did not compare the retention of maxillary dentures produced by conventional compression molding and CAD/CAM milling to the injection molding or 3D printing techniques.

CONCLUSIONS

Considering the limitations of this study, the following conclusions were drawn:

1- Conventional clinical procedures and processing techniques produced maxillary dentures with higher retention than that of dentures produced by digital workflow depending on optical impressions and scanning of conventional jaw relationships record.

2- Combining conventional and digital workflows produced maxillary dentures with higher retention than retention of maxillary dentures produced from either conventional or digital workflows.

3- The direct intra-oral digital impression was thought to be the source of reduced retention in group III dentures as compared to the conventional impression in group I, or the digital impression produced from scanning of the master cast in group II.

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