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EVALUATION OF BITING FORCE BETWEEN CONVENTIONAL AND 3D PRINTED DENTURES (A CROSSOVER STUDY)

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ABSTRACT

Aim of study: To evaluate and compare biting force (BF) and biting force changes between conventional complete (CD) dentures and 3D printed dentures.

Materials & Methods: 14 completely edentulous patients were selected from the out-patient clinic, Removable Prosthodontic Department, Beni-Suef University with age range 45–55 years with a good general and oral health. Each patient received two set of dentures, CDs and 3D printed dentures. They were asked to wear and use each denture set for 3 months but with a 2-week wash out period between them. The sequence of the dentures was randomly assigned for each patient. BF was measured with an occlusal force meter three times (at baseline, after 1 month, and after 3 months) at the 1st molar area bilaterally. The mean of the records were considered to be the patient's maximum biting force.

Results: There was a statistically significant increase in the mean values of BF in the two studied groups with insignificant difference between mean values of BF between the right & left sides and BF mean values were significantly higher with the 3D printed dentures than with the conventional complete dentures.

Conclusion: Within the limitations of this study, it may be concluded that biting force increases by time in complete denture wearers. 3D printed dentures may provide better biting force than conventionally constructed dentures.

KEYWORDS: Bite force, complete dentures, CAD CAM, 3D printed denture.

INTRODUCTION

For decades conventional complete dentures (CDs) have been the most prevalent treatment for completely edentulous patients, it has been shown to increase patient happiness and restore compromised abilities including phonetics, appearance, and chewing ability.[1,2] The ability to customize the teeth position and verify every step before insertion of the dentures is a significant advantage of CDs, however, disadvantages to be considered when

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fabricating CDs includes: time consumed for both dentist and patient due to multiple appointments as well as the laboratory costs and time are uncertain. Moreover, polymerization shrinkage from denture processing can cause poor adaptation between the denture base and the underlying tissues; also the processing porosity can allow accumulation of microorganisms. [3]

Computer-aided design/computer-aided manufacture (CAD/CAM) technology has become more popular in dentistry. [4] CAD/CAM technology is used to manufacture CDs. It has solved the problems associated with CDs, allowing improvement in denture fitness and retention through the use of digital workflows. It has been stated that the CAD/CAM technology allows patients to acquire their entire dentures in fewer appointments than the conventional procedures which requires five or six visits. Moreover, CAD/CAM technology has permitted the archiving of 3D data for use in denture creation at any moment. It used subtractive (milling) and additive techniques such as 3D printing or rapid prototyping for manufacturing. [5, 6, 7]

It was concluded that various techniques of digital manufacturing of CDs showed similar or superior clinical performance than traditional CDs and did not influence patient reported outcome. [8]

In edentulous patients the masticatory function is significantly compromised, compared with that of dentate subjects. [9] Maximum biting power is an important component in determining the state of the masticatory system. Bite force has been found to have a considerable impact on masticatory performance in participants wearing overdentures, full dentures, and natural teeth [10, 11]. Bite force is gradually diminished from fully dentate subjects, to subjects with fixed restorations to subjects with removable partial dentures and complete denture wearers. [12]

Retention, stability, and support should be considered for complete denture wearers to enhance mastication and improve overall function. Different treatment modalities have been advocated to increase denture's retention and stability including the use of thermoplastic denture base, [13] to improve denture adaptation or by using CAD/CAM fabricated dentures. Higher retention values was observed for CAD/CAM milled bases compared with conventional bases which was attributed to the decrease or absence of polymerization shrinkage of the printed bases, as well as improved fit of the CAD/CAM milled bases. [14, 15, 16]

On comparing the CAD/CAM fabricated dentures with the conventional CDs regarding maximum biting force and chewing efficiency, the CAD/CAM fabricated dentures (both 3D printed and milled) showed more superior results than the conventional CDs. [17]

Until now few studies investigated the difference of biting forces as well as the changes of biting force by time between conventional dentures and CAD/CAM complete dentures whether printed or milled. The aim of this study was to evaluate and compare biting force and biting force changes between conventional and 3D printed CDs. The null hypotheses were that, there would be no significant differences in biting force between conventional and 3D Printed dentures and the biting forces will not increase by time.

MATERIALS AND METHODS

Sample size:

Sample size was calculated depending on a previous study by ***Al-Wakeel et al*** [18]. According to this study, the minimally accepted sample size was 12 cases, when the mean ± standard deviation of biting forces in conventional complete denture was 131.34 ± 44.75, the estimated mean difference was 400, when the power was 80 % & type I error probability was 0.05. Total sample size was increased to 14 to compensate for 10 % drop out. Sample size was performed by P.S.Power 3.1.6.

Ethical consideration:

All the patients were informed about the treatment plan and all possible complications. After their approval, they signed an informed consent. Beni-Suef University Ethical Committee issued a certificate of approval bearing the approval number: # REC-FDBSU/06042023-02/AM.

A total of 14 completely edentulous patients were selected from the out-patient clinic of the Removable Prosthodontic Department, Beni-Suef University.

Inclusion criteria:

1. Male patients with the age ranging between 45-55 years old
2. Angle's class I maxilla-mandibular relation with sufficient inter arch space.
3. Free from any systemic diseases.
4. Maxillary and mandibular residual alveolar ridges covered with healthy mucosa.

Exclusion criteria:

1. TMJ disorders.
2. Abnormal habits, e.g. bruxism, clenching, smoking or alcoholism.
3. Atrophy or poor control of the muscles of mastication.
4. History of radiation therapy in the head and neck region.
5. Un-cooperative patients.

Denture construction:

A. Conventional denture construction:

Irreversible hydrocolloid (CA 37 Cavex, Holland) impression material was used for primary impression making to produce study casts onto which acrylic resin (Acrostone, Egypt) custom trays were constructed and secondary impression by metallic oxide impression material (Cavex, Holland) was made after border molding of the tray .The master casts were poured into hard dental stone.

Occlusion blocks were constructed and a maxillary face bow (Bio Art, Elite, Brazil) record was obtained for mounting the maxillary cast on a semi-adjustable articulator (Bio Art, Articulator A7 Plus, Brazil) while the mandibular cast was mounted by centric occluding relation using the check bite technique. Setting up of anatomic teeth (Acrostone, Egypt) following the lingualized occlusal concept, try-in of the waxed up denture was made, a putty index was made for the waxed-up try-in to recreate the thickness of the printed denture's polished surface as well as the labial and buccal teeth surfaces later on. The master cast ***fig (1)*** and the waxed-up try-in were scanned (Medit i500 scanner, S.Korea) for future use for the 3D printed dentures followed by processing of the dentures by the conventional technique. Denture insertion with adjustment of the denture fitting surface using pressure indicating paste and occlusal adjustment by clinical remounting were performed; the patient was given instructions for post-insertion care.

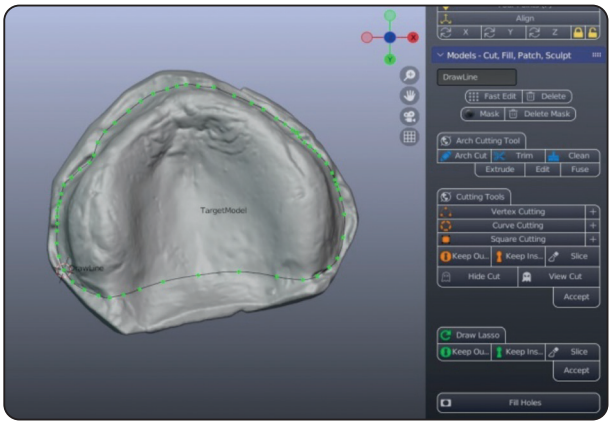

Fig. (1) Master cast scanned

B. 3D printed dentures:

The previous scanned master cast and the waxed up try –in were translated into stereolithography (STL) files. The master cast superimposition with the waxed-up try-in was made and the final design of the prosthesis were finalized by Blender Software

(Blender Australian) ***fig(2)***, the 3D virtual complete denture was printed with photosynthesized resin. (Phrozen Standard Resin, Taiwan)

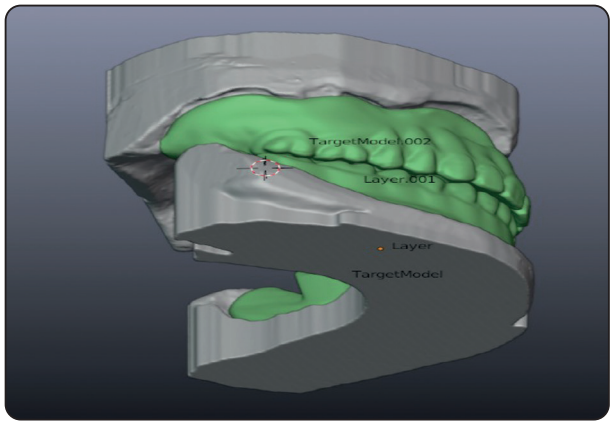

Fig (2): Virtual complete denture finalized by Blender Software

The 3D printed monolithic PMMA denture was tried in the patient's mouth ***fig (3)*** to assess facial proportion symmetry with artificial teeth, phonetics, vertical dimension, and occlusion; any small adjustments to tooth position were made. Visio.lign (Visio.lign, bredent Gmbh, Germany) was then used to color the 3D printed dentures in three distinct colors to simulate natural appearance. The putty index was used to recreate the polished surface and the teeth labial and buccal surfaces during coloring operations; finally the denture was inserted and adjusted as previously described. ***fig (4)***

Fig (3): Try in of the 3D printed denture in the patient's mouth

Fig (4): 3D printed denture inserted in the patient's mouth

Randomization & follow up:

After constructing both sets of the conventional and 3D printed dentures, the sequence of their use was randomly assigned for each patient. Patients were asked to randomly draw from a container holding 14 opaque properly folded tickets. 7 tickets with the sequence conventional then 3D printed denture and 7 tickets with the sequence 3D printed then conventional denture.

All patients were allowed to use each denture set (based on the sequence assigned) for 3 months with a 2 week wash out period between them. Biting force was evaluated for all patients one week after denture insertion (baseline record), then 1 month and 3 months after denture use. The same follow-up was followed for both sets of dentures.

Evaluation of biting force:

Biting force was measured by an occlusal force meter which is a hydraulic pressure device with disposable plastic cap, the patient was asked to bite on the plastic cap. Records were measured at the first molar region of the right and left sides three times each. Range of measurement was 0–1000 kN with an accuracy of ± 1 N (GM10, Nagano Keiki, Tokyo, Japan). ***fig(5)***

The maximum occlusal force in Kilonewton (kN) was recorded. The mean of the three records was considered to be the patient's maximum biting force.

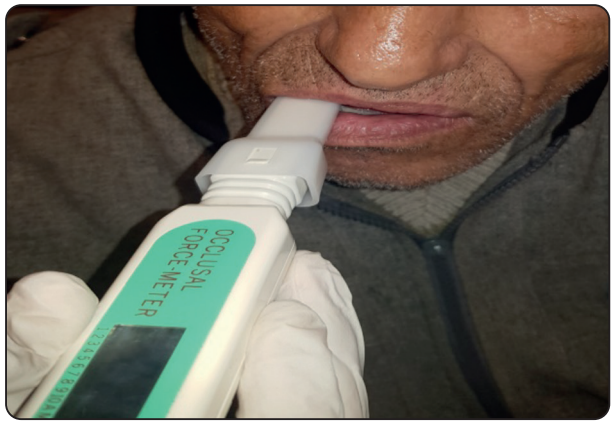

Fig (5): Biting force measured using an occlusal force meter

Statistical analysis:

All data were presented as mean and standard deviation of biting forces for both dentures, Statistical analysis was performed with SPSS 16 ® (Statistical Package for Scientific Studies), Graph pad prism & windows excel.

Exploration of the given data was performed using Shapiro-Wilk test and Kolmogorov-Smirnov test for normality which revealed that the significant level (P-value) was insignificant as P-value >0.05 which indicated data originated from normal distribution (parametric data) resembling normal Bell curve. Accordingly, comparison between different intervals was performed by using Repeated measures ANOVA test followed by Tukey`s Post Hoc test for multiple comparisons. Comparison between the two dentures was performed by using independent t test, while comparison between right and left sides was performed by using Paired t test.

RESULTS

Comparison between conventional & 3D printed dentures:

Mean and standard deviation of biting forces and biting force changes in right and left sides for the conventional denture and 3D printed denture are presented in Table (1) and figure (6). Statistical analysis revealed significant differences between both dentures at all follow up periods for both the right and left sides as P= 0.0001 as seen in Table (1) and figure (6).

TABLE (1) Comparison between conventional and 3D printed dentures regarding biting forces and biting force changes at all follow up periods and at all-time intervals in the right and left sides:

Comparison Conventional and 3D printed dentures			Conventional Denture		3D printed denture (CAD / CAM Denture)		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		P value
			Mean (kN)	Standard Deviation	Mean (kN)	Standard Deviation			Lower	Upper	
(Biting forces)	Left	Base line	0.73	0.05	0.86	0.05	-0.13	0.02	-0.17	-0.09	0.0001*
		1month	0.85	0.05	1.09	0.10	-0.24	0.03	-0.30	-0.17	0.0001*
		3 month	1.09	0.04	1.46	0.10	-0.37	0.03	-0.43	-0.31	0.0001*
	Right	Base line	0.75	0.07	0.87	0.04	-0.12	0.02	-0.16	-0.08	0.0001*
		1month	0.86	0.04	1.10	0.05	-0.23	0.02	-0.27	-0.19	0.0001*
		3 month	1.09	0.05	1.46	0.10	-0.37	0.03	-0.43	-0.31	0.0001*
(Biting force changes)	Left	Baseline- 1 month	0.12	0.05	0.23	0.10	-0.11	0.03	-0.17	-0.04	0.0001*
		1 month- 3 months	0.24	0.04	0.37	0.09	-0.14	0.03	-0.19	-0.08	0.0001*
		Baseline- 3months	0.36	0.05	0.60	0.10	-0.24	0.03	-0.30	-0.18	0.0001*
	Right	Baseline- 1month	0.12	0.06	0.23	0.04	-0.11	0.02	-0.15	-0.07	0.0001*
		1 month- 3months	0.23	0.08	0.36	0.10	-0.14	0.04	-0.21	-0.06	0.0001*
		Baseline- 3months	0.35	0.09	0.59	0.10	-0.25	0.03	-0.32	-0.18	0.0001*

Significant difference as P<0.05.

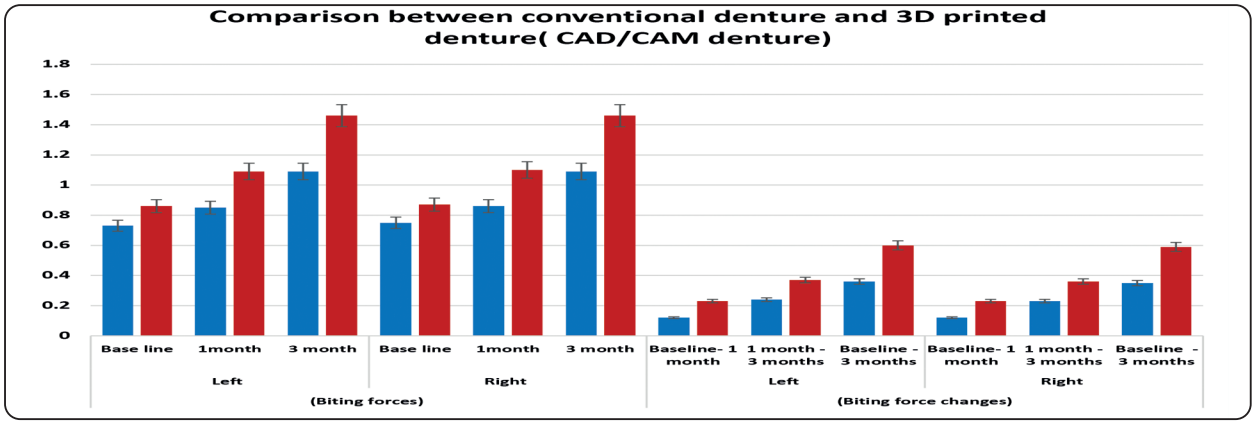

Fig (6) Bar chart showing biting forces and biting forces changes between right and left sides at all follow up periods.

Comparison between right and left sides for both dentures:

Mean and standard deviation of biting forces and biting force changes in right and left sides of conventional denture and 3D printed denture are presented in Table (2) and figure(7).

Statistical analysis revealed insignificant differences between the right and left sides for both the conventional denture and 3D printed denture as P>0.05, as seen in table (2) and figure (7). This was true for all follow-up periods and time intervals.

TABLE (2) Comparison between biting forces and biting force changes at right and left sides for both dentures:

Comparison between right and left sides			Left side		Right side		Paired Samples Test					
							Paired Differences					
			Mean (kN)	Standard Deviation	Mean (kN)	Standard Deviation	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		P value
										Lower	Upper	
Biting forces	Conventional Denture	Base line	0.73	0.05	0.75	0.07	0.01	0.08	0.02	-0.04	0.06	0.59
		1month	0.85	0.05	0.86	0.04	0.01	0.07	0.02	-0.03	0.05	0.55
		3 month	1.09	0.04	1.09	0.05	0.001	0.06	0.02	-0.04	0.03	0.93
	CAD / CAM Denture	Base line	0.86	0.05	0.87	0.04	0.01	0.05	0.01	-0.02	0.03	0.78
		1month	1.09	0.10	1.10	0.05	0.01	0.11	0.03	-0.06	0.07	0.86
		3 month	1.46	0.10	1.46	0.10	0.001	0.08	0.02	-0.05	0.04	0.87
Biting forces changes	Conventional Denture	Baseline- 1 month	0.12	0.05	0.12	0.06	0.001	0.03	0.01	-0.02	0.02	0.69
		1 month - 3 months	0.24	0.04	0.23	0.08	0.01	0.10	0.03	-0.07	0.05	0.70
		Baseline - 3 months	0.36	0.05	0.35	0.09	0.01	0.10	0.03	-0.07	0.05	0.61
	CAD / CAM Denture	Baseline- 1 month	0.23	0.10	0.23	0.04	0.001	0.11	0.03	-0.06	0.07	0.92
		1 month - 3 months	0.37	0.09	0.36	0.10	0.01	0.11	0.03	-0.07	0.05	0.74
		Baseline - 3 months	0.60	0.10	0.59	0.10	0.01	0.11	0.03	-0.07	0.06	0.83

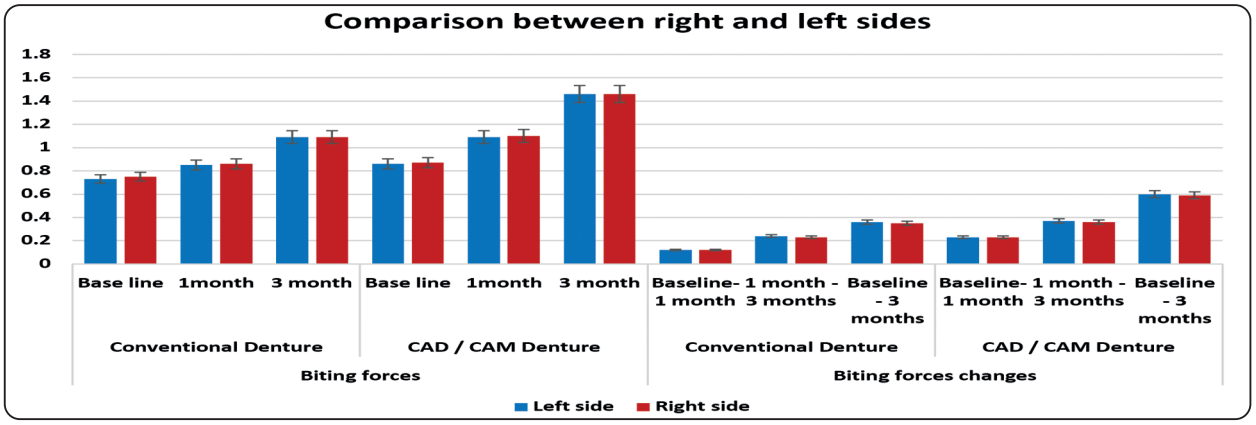

Fig (7) Bar chart showing biting forces and biting force changes at right and left sides for both dentures.

Effect of time on bite force and bite force changes for both dentures:

Mean and standard deviation of biting forces and biting force changes at different intervals of conventional denture and 3D printed denture are presented in Table (3) and figure (8).

Biting force increased by time for both denture types, statistical analysis revealed significant differences among all-time intervals for both the conventional denture and 3D printed denture as $P<0.05$, as seen in Table (3) and figure (8).

TABLE (3) Comparison between biting forces at baseline, after 1month and after 3months for both dentures:

			Baseline (baseline – 1 month)		1 month (1 month – 3 months)		3 months (baseline – 3 months)		P value
			Mean (kN)	Standard Deviation	Mean (kN)	Standard Deviation	Mean (kN)	Standard Deviation	
Biting forces	Conventional Denture	**Left**	0.73	0.05	0.85	0.05	1.09	0.04	0.0001*
		Right	0.75	0.07	0.86	0.04	1.09	0.05	0.0001*
	3D printed Denture	**Left**	0.86	0.05	1.09	0.10	1.46	0.10	0.0001*
		Right	0.87	0.04	1.10	0.05	1.46	0.10	0.0001*
Biting forces changes	Conventional Denture	**Left**	0.12	0.05	0.24	0.04	0.36	0.05	0.0001*
		Right	0.12	0.06	0.23	0.08	0.35	0.09	0.0001*
	3D printed Denture	**Left**	0.23	0.10	0.37	0.09	0.60	0.10	0.0001*
		Right	0.23	0.04	0.36	0.10	0.59	0.10	0.0001*

*Significant difference as $P<0.05$.

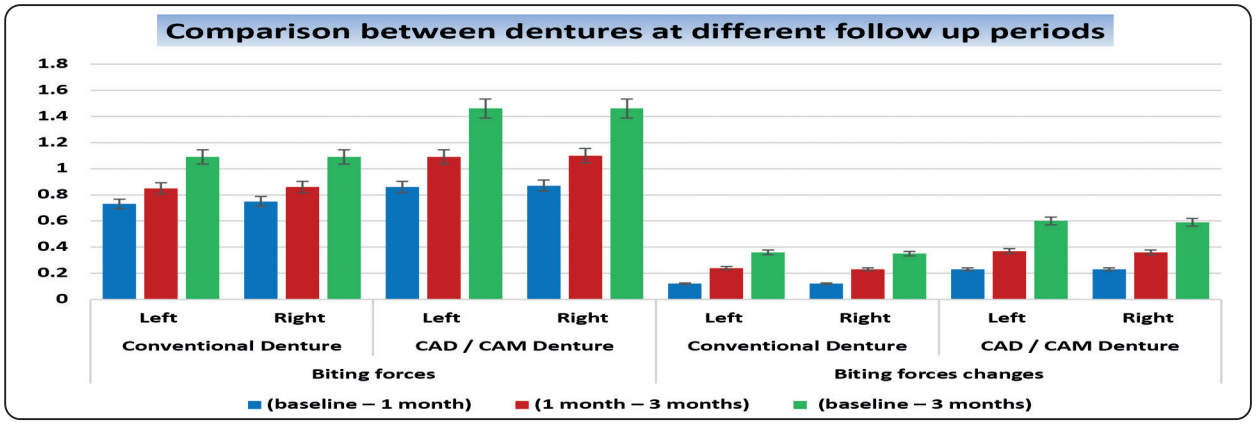

Fig. (8) Bar chart showing biting forces at baseline, after 1month, and after 3months for both dentures.

DISCUSSION

In the present study, there was a significant increase in biting force by time and biting force was significantly higher for the 3D printed dentures compared to the conventionally constructed dentures. Thus, both null hypotheses were rejected.

To prevent compromising denture stability and consequently could have affected the biting force; the lingualized occlusion concept was used for setting up of the artificial teeth as it allows for minimal occlusal adjustments and good force distribution for better retention and stability of the denture. [19]

The results of the present study revealed that the biting force increased significantly by time and throughout the follow- up periods for both the conventional and the 3D printed dentures

This finding is in agreement with previous studies that had shown that the biting force & masticatory efficiency increase significantly with newly fit CDs and improves gradually over time. [20, 21, 22]

This could be attributed to the improved retention & stability of the CDs that increased because of the denture settling that occurs by time as well as the gradual increase in neuromuscular control on the denture which subsequently improves the functional adaptation to the new dentures, increases the patient's sense of security towards the denture and consequently improving the biting force. [23]. When neuromuscular adaptation increases, the masticatory muscles are not required to stabilize the denture anymore & are used mainly for mastication hence more biting forces. CAD-CAM dentures with more retentive denture bases as reported in previous studies may minimize the use of masticatory muscles to stabilize dentures besides giving the patient better confidence and consequently better security and more biting force & masticatory efficiency values. [24, 25, 26]

Results of the current study showed that the 3D printed dentures provided significantly higher mean biting force values than conventionally constructed dentures. This finding may be due to the better fitness of the 3D printed denture as well as the absence of the processing steps of the conventional denture with its accompanying occlusion errors which in turn leads to minimal post insertion occlusal adjustment. [27] It is worth mentioning that refinement of occlusion is made twice during the virtual set up of artificial teeth on the EXCOCAD software leading to less premature contacts, better occlusal balance & better denture stability. This is in agreement with ***McLaughlin et al.*** [28] whom reported that the use of CAD/CAM record bases for complete denture fabrication produces a well-fitting denture with less occlusal errors.

Furthermore, it has been reported that digitally

fabricated CDs possess good adaptation and retention than conventional CDs, [29, 30] biting forces are directly related to the denture's retention. The decrease in polymerization shrinkage that is reported with printed denture as well as the improved fitness have been described as factors allowing for higher retention compared with conventional denture bases. [16, 31, 32] this may justify the higher biting forces seen with the 3D printed dentures.

These results may agree with ***Kattadiyil et al.*** [33] whom compared the clinical outcomes of CAD/CAM & conventional CDs and patient satisfaction. They stated that a CAD/CAM complete denture gives a promising outcome.

The results of this study had revealed that there was a statistically insignificant difference in the mean values of biting force between right & left sides for both dentures throughout the study period. This finding is in agreement with ***Balana et al.*** [34] that had shown that the mean bite forces between right and left side in conventional complete dentures was found to be statistically insignificant. This may be attributed to that all prosthesis was accurately occlusally balanced after adjusting the occlusion at the insertion visit which allowed for the insignificant difference between the left and right sides.

CONCLUSIONS

Within the limitations of this study, it may be concluded that biting force increases by time in complete denture wearers. 3D printed dentures (CAD/CAM dentures) may provide better biting force than conventionally constructed dentures.

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