Comparative study of retention of mandibular denture bases three-dimensional (3D) printing technique and metal-reinforced acrylic resin

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Abstract

Objective: retention evaluation of mandibular complete denture fabricated by different method
Methods: This in-vivo study was conducted over mandibular complete denture for completely edentulous patients. This study consisted of 2 groups according to method of fabrication of mandibular complete denture: Group I: mandibular complete denture fabricated by 3D printing technique, Group II: mandibular complete denture with metal reinforced fabricated by conventional technique. Retention were evaluated for both groups
Results:
Conclusion:

Keywords: complete denture, metal reinforced denture, retention, Digital, 3D printing

Introduction:

Edentulism has been a serious public health problem in industrialized countries due to population aging and in developing countries due to poor oral care. The life quality and nutrition intake are impacted for edentulous patients due to edentulism. Despite an anticipated decrease in the age-specific rates of edentulism, the demand for complete dentures will continuously increase in the next decades [(1)]. Edentulism is even classified as a physical handicap by the World Health Organization [(2)].

Retention plays a vital role in the success of the complete denture, and therefore every stage of denture construction should be given due importance. Effective retention is attained by the close mucosal contact of the denture base. Polymethyl methacrylate (PMMA) is the material of choice for the fabrication of the majority of dentures. During the polymerization process, dimensional shrinkage of the resin occurs. Shrinkage, which is caused by the differences in the densities of the monomer and the polymer, results in a lifting of the denture base away from the posterior palate as a result of polymerization [(3)].

Alternative materials and techniques are available to overcome the shortcomings of heat cured PMMA, including metal alloys and digital technique. Metal alloys, offer superior mechanical and physical properties in comparison with PMMA. They are stronger, with higher fatigue and fracture strengths. In addition, they can be cast in thin sections without compromising their rigidity or fracture resistance. This property, in addition to their high thermal conductivity, provides patients with a natural “feel” to the prosthesis [(4)].

Metallic denture bases are also biocompatible, dimensionally stable with high surface polish which facilitates hygiene maintenance. They are particularly useful

in situations with high risk of fracture that require strengthening of the denture base, as in cases with bruxism or in single maxillary dentures [5].

CAD- CAM technology has been widely used in the field of prosthodontics. Construction of complete denture using CAD- CAM is characterized by ease of fabrication with reduced laboratory procedures. It also leads to higher dimensional accuracy and standardized fabrication [6].

Digital design ensures consistent thickness of denture bases which can be adjusted and kept minimal. In addition, the presence of digital data enables future fabrication of dentures in case of lost ones [7].

Al helal in 2017 stated that the retention of milled dentures from pre-polymerized poly-methyl methacrylate is better than that of conventional heat polymerized acrylic resin due to less polymerization shrinkage with subsequent superior adaptation. [8]

Soygun et al in 2013 compared the mechanical properties of polyamide with the conventional PMMA and fiber reinforced PMMA denture base materials; it was revealed that the polyamide denture base material had the highest transverse strength, without any fracture. It was also observed that the values of maximum impact strength were the highest for polyamide (9)

Retention measured by Strain gauge which is a sensor device which is used to convert force, pressure and tension (mechanical strain) in to change in electric resistance (voltage output) that can be measured, it can be used in in-vivo and in-vitro studies.[10]

Materials and Methods:

Study design:

The National Research Centre's Medical Research Ethics Committee accepted the research protocol on 21/07/2022 (no. of approval: 8887082022).

Completely edentulous patients were selected from the outpatient clinic of the Medical Excellence Centre of the National Research Centre, Cairo, Egypt and College of Oral and Dental surgery, Misr University for Science and technology

according to the following inclusion criteria: patients aged from 45-75 years and had been completely edentulous for a minimum period of 1-year, normal maxillary-mandibular relationship, healthy mucosa, and normal salivary flow. While the exclusion criteria were: smoker patients or patients having hard or soft tissue pathology, severe ridge undercut, and patients who had received radiation to the head and neck region.
This study divided into 2 groups according to type of denture received by the patients:

Group I: Patients received maxillary and mandibular rapid prototype complete denture

- Retention was measured at time of insertion and after 3 weak and after 6 weak using the retention force gauge device

Group II: Patients received mandibular complete denture constructed from polyamide reinforced with metal frame work and maxillary dentures constructed from conventional Poly-Methyl Methacrylate

- Retention was measured at time of insertion and after 3 weak and after 6 weak using the retention force gauge device

Sample Size Calculation:

A total sample size of 12 will be sufficient with the power of 80% and 5% significance level. This number will be increased to 20 (10 in each of the two groups) to compensate for follow-up losses. The sample size was determined through the application of the G Power program.

Construction of the 3D model:

For rapid prototype complete denture base, Preliminary impressions was made using irreversible Hydrocolloid Alginate (Cavex Holland BV) then definitive impression and recorded horizontal relationship were done in one visit and sent to a digital laboratory for scanning and 3D printing of the CDs.

The master casts were digitalized using and extraoral 3D scanner * , at which the cast holder used to fix the cast in place,
The digital image (STL file) were imported to Exocad* digital design software to oriented the cast according to proposed insertion and removal pathway and to draw extension of denture base at the depth of vestibules and make design of denture base.

Printing step: the designed denture base were export as STL file and sent to 3D printer software, the denture base were printed according to Digital Light projection (DLP) technology * using Next Dent Baes Liquid* which is a monomer based on acrylic ester. Then the denture base were finished and polished except area at crest of the ridge.

Bite registration using printed denture base: wax occlusal rim were made on the printed denture base, then inserted in patient mouth to adjust lip support and vertical diminution and for registration jaw relation (centric relation)

Setting artificial teeth were carried on the same way as in conventional complete denture, after try in maxillary and mandibular denture, the artificial teeth attached to digital denture base by self cured acrylic resin.

Finally the finished denture was inserted in patient mouth to checking retention and stability and occlusion

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* Exocad GmbH Julius- Reiber- StraBe 37 64293 Darmstadt Germany

* Digital light projection (DLP): Mogassam Dentcase printer, Delaware, USA

* Next Dent base liquid: by 3D systems, Soesterberg, Netherlands

Construction of metal reinforced complete denture:

Maxillary and mandibular preliminary impressions were made for each patient using irreversible hydrocolloid impression material (alginate) in stock tray then special trays were constructed for final impression registration.

Centric relation at the proper vertical dimension of occlusion was recorded using wax wafer registration, and then Trial dentures were tried in the patient's mouth for appropriate vertical and horizontal maxilla-mandibular relation

Finally, duplication of the master cast using silicon material was done to obtain a refractory cast for the construction of the metal framework

Metal framework: Two rows of mesh wax pattern were adapted on the refractory cast, followed by spruing, investing, burning out and casting of the metal framework.

The metal framework was returned in to the master cast and checked for adaptation. Sealing of the mandibular trial denture base to the master cast, waxing up and attaching the sprue formers was done to make the channels for injection of polyamide into mold, The cartridge was placed in a cartridge carrier which was then placed in electric cartridge furnace* used for softening of thermoplastic denture base material. The cartridge was placed on the inlet of the flask and was compressed in mechanical compressor.

Finally Denture insertion was made checking extension, retention, stability and occlusion

* Thermopress Flask, Bredent, GmbH, Senden/ Witzighausen, Germany

Retentive force Measurements

The measuring device used to meseaure retention is Digital force gauge *(is an advanced type of force meter device used to Measure Tension or Compression force.

After determining the geometric center for mandibular denture, then mark a point on the plaster base.

Three "V" shaped grooves were created on the polished surface of the lower denture. (Two grooves were created at the retromolar pad area just distal to the second molar of both sides. The other one was made on the lingual flange at the midline region below the central incisors)

A wrought wire of 1 mm in diameter was then bent at its center and adjusted so as not to encroach on the tongue space and to run 2 cm above the occlusal plane from the retromolar pad groove of one side to the retromolar pad groove of the other side.

* Digital Force Gauge EXTECH 475044.

Then free ends of the three wires were then fixed to the polished surface of the lower denture by self-cured acrylic resin.

Retention of mandibular dentures was assessed as follows:

After denture insertion, The metallic probe of the digital force-meter was then attached to the c-shaped metal hook created at the geometric center of the mandibular dentures and a vertical pulling force was applied to measure denture retention. Retention strength was measured in newtons.

Statistical analysis:

All data were presented as mean &standard deviation. Data were presented 1 table & 1 graph. 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 that all data originated from normal distribution (parametric data) resembling normal Bell curve.

Accordingly, comparison between different groups was performed by using Independent t-test, while comparison between different intervals was performed by using One Way ANOVA test followed by Tukey`s Post Hoc test for multiple comparisons.

Effect of time (table 1 and figure 1):

In group I, there was a significant difference between all intervals as $P<0.05$, at delivery was significantly the lowest retention (10.58 ± 0.31), while there was

insignificant difference between after 3 months (11.92 ± 0.56) and after 6 months (12.17 ± 0.49) with 15.9% percent of increase in retention for 6 months.

In group II, there was a significant difference between all intervals as P<0.05, at delivery was significantly the lowest retention (16.54 ± 0.52), then after 3 months (18.49 ± 0.58), while after 6 months (19.87 ± 0.59) was significantly the highest with 20.00% percent of increase in retention for 6 months.

Effect of different construction techniques (table 2 and figure 2):

Comparison between group I & II revealed that group II was significantly higher than group I at all intervals as P <0.05

Table (1): Mean and standard deviation of retention in both groups and comparison between different intervals with percent of change in each group:

	Follow up	M	SD	% change	P value
Group I (3D printed denture)	**At delivery**	10.58 [a]	0.31	15.90%	<0.0001*
	After 3 weeks	11.92 [b]	0.56		
	After 6 weeks	12.17 [b]	0.49		
Group II (metal reinforced denture)	**At delivery**	16.54 [a]	0.52	20.00%	<0.0001*
	After 3 weeks	18.49 [b]	0.58		
	After 6 weeks	19.87 [c]	0.59		

*M: mean SD: standard deviation *Significant difference at P <0.05*
Means with different superscript letters were significantly different as P <0.05
Means with the same superscript letters were insignificantly different as P >0.05

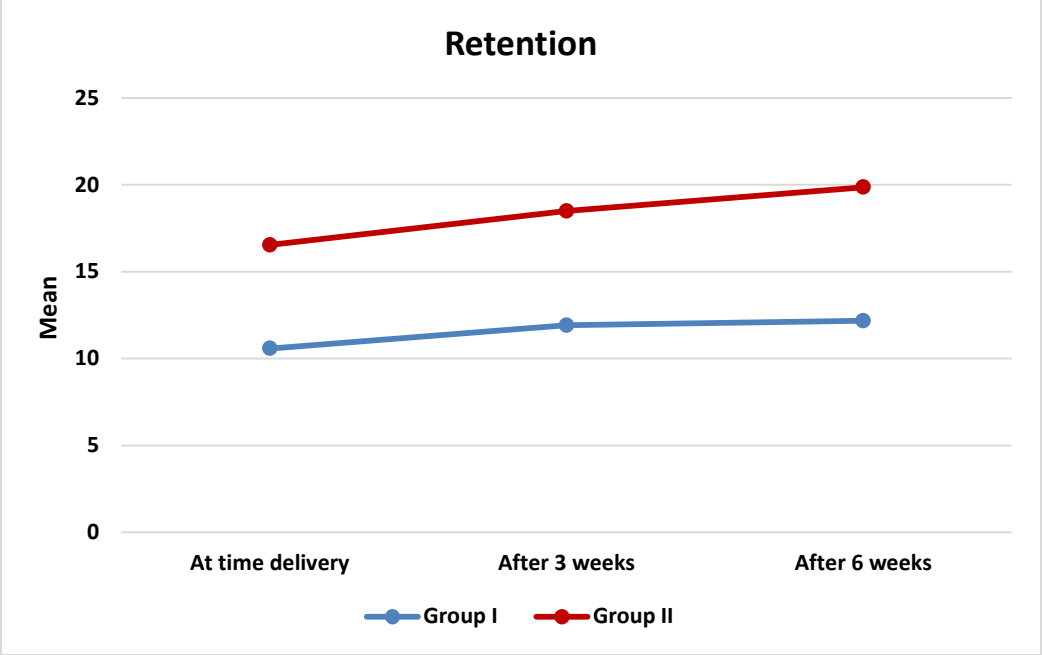

Figure (1): line chart representing retention changes of both groups during different intervals.

Table (2): Comparison between group I & II regarding retention at different intervals using Independent t-test:

Interval	N	Group I		Group II		Independent t-test			
						P value	MD ± SEM	95% CI	
		M	SD	M	SD			L	U
At time delivery	7	10.58	0.31	16.54	0.52	0.0001 *	5.9 ± 0.2	5.4	6.4
After 3 weeks	7	11.92	0.56	18.49	0.58	0.0001 *	6.6 ± 0.3	5.9	7.2
After 6 weeks	7	13.24	0.49	19.87	0.5	0.0001 *	6.63± 0.3	6.05	7.21

*M: mean SD: standard deviation *Significant difference at P <0.05*
Difference between means (B - A) ± standard error of mean
CI: confidence intervals at 95% (U; upper / L: lower)

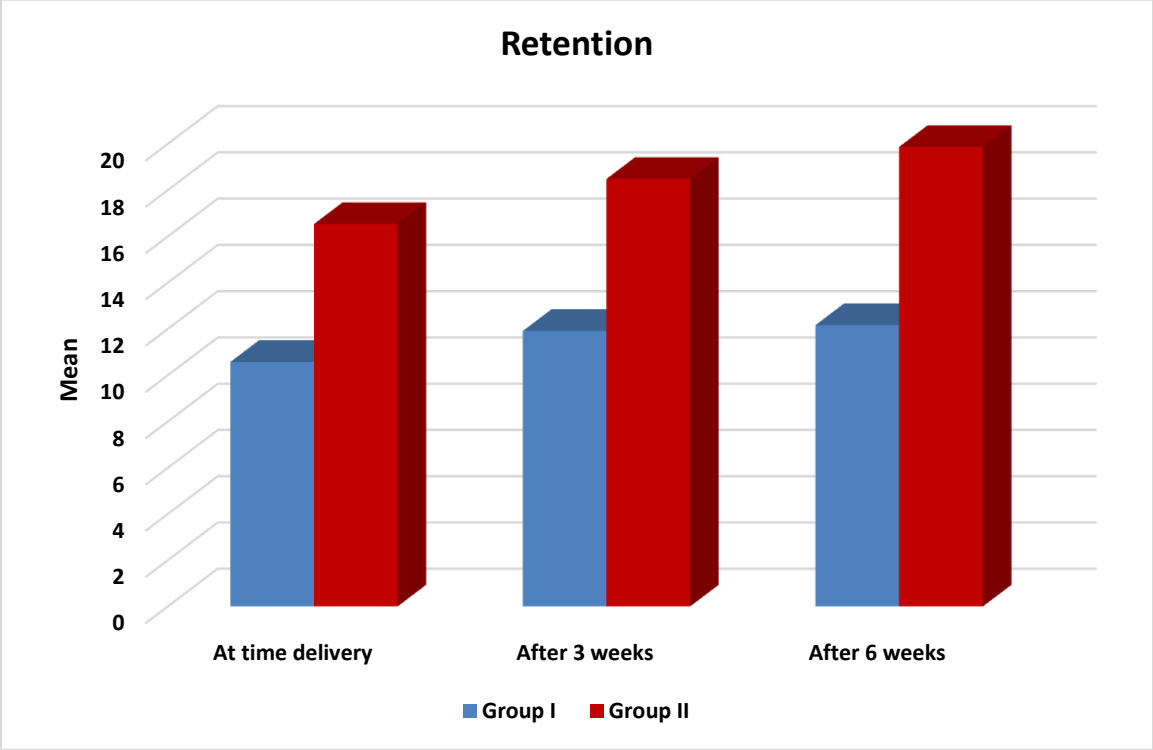

Figure (2): Bar chart representing retention in both groups.

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