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Original Article

Effect of Three Different Pick up Retaining Materials on Flexural Strength of A 3D printed Overdenture Base in a Single Implant Retained Mandibular Overdenture: An In-Vitro Study

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Abstract

Aim: Comparing three chair-sided pickup retaining materials (bis acryl auto polymerized composite, improved methyl methacrylate free self-curing hard reline and self-cured poly methyl methacrylate) in terms of their effect on the flexural strength of 3D printed overdenture base for chairside attachment pick up which simulate clinical condition of a midline implant mandibular overdenture.

Subjects and methods: In this in-vitro study, a total of 36 denture base blocks 64x10x4mm ([ISO] standard 1567) with a hollow were digitally designed and 3D printed mimicking the overdenture base ,then equally divided between three different pick up materials, all samples were picked up and subjected to thermal cycling (5000 cycles) prior to 3 point bending test to compare flexural strength.

Results: showed that the auto-polymerized acrylic resin group exhibited much higher flexural values than the other groups. There was insignificant difference among the other groups.

Conclusion: When auto-polymerizing acrylic resin group (Acrostone) was used as a pick-up material, the flexural strength of a 3D printed overdenture base was significantly higher than when a hard reline (Gc reline) and auto-polymerized composite Resin (Luxa) were used.

Keywords: Mandibular Overdenture, Digital dentistry, Flexural strength (3 point bending test), Pick up materials, Thermocycling.

I. INTRODUCTION

Edentulism is a debilitating and irreversible condition that is much more common in the older age groups than the younger age groups. Complete dentures have been and remain the primary treatment for edentulous patients for the past hundred years ***(Cunha-Cruz, Hujoel and Nadanovsky et al., 2007).***

A mandibular denture is a difficult prosthesis to manage, so implants may provide an excellent option to overcome the lack of retention and support of complete denture ***(Doundoulakis et al., 2003).***

An edentulous mandible can be restored with a fixed or removable prosthesis. Removable implant supported overdentures are a more affordable treatment option that can be removed by the patient allowing for better oral hygiene and require fewer implants than fixed overdentures. Also, esthetically it gives a better outcome in case of loss of soft and hard tissue ***(Chee and Jivraj et al., 2006; Hoffmann et al., 2006).***

The Implant overdenture attachment system is a mechanical device used to retain, stabilize and secure the prosthesis, it consists of two parts: One part of the attachment system is screwed into the implant (patrix) and the other incorporated in the corresponding overdenture's fitting surface (matrix) which fit closely together ***(Burns et al., 2000).***

Two consensus statements claimed that removable implant-supported overdentures with two implants should be considered the standard of choice for the treatment of the edentulous mandible ***(Thomason et al., 2009).***

Meanwhile, an implant in the midline has been recently claimed to offer satisfactory retention for the overdenture wearer and suggested for peoples who cannot afford implant therapy and bone grafting, but still there is insufficient evidence for applicability of this alternative treatment option ***(Harder et al., 2011; Fahd, Abbas and Farouk, et al., 2018).***

A new era in prosthodontics has begun with the use of CAD/CAM systems in overdentures fabrication and implants. There are Various CAD/CAM systems available for designing and manufacturing of prosthesis ***(Han et al., 2017).***

Computer Assisted Design (CAD) is the use of computer software to design restoration in 3 dimensions (3D). With this type of software can convert scanned images into digital models for designing prostheses. The construction data can be stored in different data formats, called Standard Transformation Language (STL files).

Computer-Assisted Manufacturing involves fabrication and production of restoration that undergoes processing and finishing before insertion into the patient's mouth ***(Beuer, Schweiger and Edelhoff et al., 2008).***

The manufacturing process may be subtractive or additive techniques, in subtractive manufacturing; 3D objects are made by successive milling of additional material from a large solid block ***(Al et al., 2019).***

While In additive manufacturing technique (3D printing); 3D objects are produced by successive deposition of material to obtain a 3D object. Once The CAD design is done, the main idea is that the 3D object is sliced into many thin layers. For each millimeter of material, there are 5–20 layers in which the machine lays down sequential layers of material that are fused to form final desired product ***(Dawood et al., 2015).***

3D Printing is a modern technology that has developed rapidly in last years as it has many advantages as saving time, lesser material wastage due to additive procedures, promising accurate marginal fit, high precision and efficiency, flexibility and ease of fabrication ***(Dawood et al., 2015; Liu, Leu and Schmit et al., 2005).***

Common clinical complication of implant retained mandibular overdenture is a fracture of denture base after impact due to flexural fatigue as the denture base is subjected to repeated chewing loads, also, thinning of denture base induced through accommodation of housing into fitting surface of denture base ***(Ajaj-ALKordy and Alsaadi et al., 2014; Domingo et al., 2013).***

The most commonly used test to estimate the strength of acrylic resin is flexural strength which is defined as the maximum stresses that can withstand before fracture when exposed to bending load ***(Chung et al., 2004).***

There are two prevalent methods which are employed to define the flexural properties of dental materials which are the ISO 40494 three-point bending tests and the biaxial test methods Currently, 3 point bending test is considered as the only screening method used for resin-based materials. The ISO standard needs a beam sample of 64 x 10 x 4 mm3 for the three-point bending test ***(Chung et al., 2004).***

The process of integrating the attachment housing into fitting surface of overdenture base using resin is called attachment pick-up. Pick up of housing can be done either directly (chairside) or indirectly (in laboratory).chairside techniques are preferred to reduce errors induced from denture processing. Traditionally, auto or light polymerizing acrylic resin is employed for direct chairside technique ***(Panittaveekul et al., 2021; Baghbani et al., 2020).***

Polymethyl methacrylate (PMMA) is considered the most common pickup material, but its mechanical properties limit denture performance.

Currently, self-curing composite materials have been introduced as chairside attachment transfer pickup material and one such material available in the market is Luxa pick up. Also, hard reline materials can be used as pick up material as “GC RELINE” which represents an improved form of self-cure, methyl methacrylate-free reline material ***(Baghbani et al., 2020).***

This study compared three different pick up retaining materials regarding their effect on flexural strength of 3Dprinted overdenture base for direct pickup of attachment housing simulating clinical condition of a midline implant mandibular overdenture.

II. SUBJECTS AND METHODS

A total of 36 bar-shaped specimens with 64 length×10 width ×4 mm thickness ([ISO] standard 1567) mimicking the overdenture base were prepared ***(Serhat Emre Ozkir and Yilmaz et al., 2017).*** The design of bar was done on solidworks software (2019 3D CAD design software), then the STL File was exported on Exocad (Dental CAD 3.1 Rijeka 2022-Usa).

Central cylindrical hollow was done which was corresponded to the flat back surface of metal housing; the diameter of this cylinder was chosen where Ø3.5mm in diameter and 2mm in height space was needed for metal housing (CWM – INNO-Korea) and the additional 1.5mm space surrounding housing for pick up material. So, the cylinder size was widened to Ø7 mm to accommodate pickup space and housing space.

Cylindrical tube was designed using Solidworks and a STLfile was exported on Exocad to previous project, then subtraction of this designed cylindrical tube from denture block was done leaving 0.5 mm of denture base material above the hollowed site.

The STLfile of virtually designed denture block with a cylinderical hollow (Ø 7×3.5 in depth) was exported to LCD printer machine (Phrozen 3D Printer-Taiwan) to print 36 denture blocks mimicking overdenture base. (n=12 per group) utilizing the photo curable liquid resin (Nextdent Denture 3D+ - Netherland),The printed blocks were cleaned and cured after removing from the platform according to manufacturer’s instruction.

To ensure centralization of housing within hollow. Marking lines were positioned to determine maximum diameter (Ø7.5mm) of the cylinder hollow mesiodistally and buccolingually. then two orthodontic wires (15 gauge) were overlied perpendicular to each other until coinciding with pre-determined marks on the hollow boundaries mesiodistally and buccolingually, fixation of wires was done using adhesive at these marks ,These marks were also marked on wire, The intersection of two wires was considered the center of the cylinder .

Also, Marks at maximum diameter on housing (3.5mm) was determined by permanent marker and then the splinted cross shape wires were put over these marks to determine the same marks on the cross shape wire. To maintain this position, Fitting surface of housing was filled with soft wax with additional 1mm then positioning of cross shape wire over it until coinciding with marks using finger pressure until hardening of wax.

During pick up step, the metal housing was picked up utilizing this cross shape wire with centrally splinted metal housing using finger pressure until marks on wire coinciding with marks of the cylinder hollow, this technique was repeated for all groups to ensure centralization of housing during pick up (Figure 1).

Pick Up Step Using Different Retaining Material:

Thirty -six overdenture base specimens were divided into three groups (n=12) .each groups received one of the following pick up materials for housing insertion as follows:

A-Auto-Polymerized Composite Resin (Luxa Pickup):

The inner surfaces of hollow were wetted using Luxatemp-Glaze and Bond then Light-cured, the auto-mixed composite was injected in the internal surface of hollow. Seating of this cross-shape wires with housing was done over this using finger pressure until the wire was hit the outer surface of the block at the predetermined marks. A moderate pressure over the wire was maintained till 2-3 minutes, after setting, the cross-shape wire was detached from the housing and the excess material was removed, trimming the junction was done, setting time completed was 6-7 minutes (Figure 2).

B-GC Hard Reline:

The housing bed was wetted with bonding agent. The solvent was allowed to air dried for 10 seconds.The powder and liquid were mixed according to the manufacturer's instructions and filled interior of the hollow using spatula.Then, Seating of this cross shape wires was done as in luxa at approximately 1 minute from start of the mix. A moderate pressure on the wire was maintained until the material reached a rubbery state. after this, the cross shape wire was removed from housing at approximately 5 minutes and 30 seconds from the start of the mix. Trimming the junction, Finishing and polishing of excess material in a usual manner were done.

C-Auto-Polymerized Acrylic Resin (Acrostone):

The housing bed was wetted with liquid monomer using a brush for 30s. powder and liquid was mixed for 10-15sec, when the material reached dough-like consistency, The auto-polymerized acrylic resin mix was placed inside the hollow, Then, cross shape wire was seated, All procedure must be completed within 2 minutes after mixing, when chemical curing started, The wire was held in the same position using finger pressure until complete setting, separation of wire from housing was done, Excess material was removed with a micro brush following conventional method.

Measuring Flexural strength utilizing universal testing machine:

Specimens were left for 48 hours prior to testing. then, All 36 samples were subjected to 5000 thermal cycle's (Robota Automated Thermal Cycle; Bilg-Turkey), After this, All specimens were mounted individually and horizontally in a loading fixture [three-point bending test assembly; two parallel stainless steel rods with span length 50 mm supporting the specimen, with the damage site located in the center of tension side]***(Serhat Emre Ozkir and Yilmaz et al., 2017)*** (Figure 3) in acomputer-controlled materials testing machine (model 3345; Instron Industrial Products, Norwood,USA) with a 5kN load cell and data were recorded using computer software .

Then, the samples were loaded in static compression until fracture at a cross speed of 5 mm/min. FS represents the limiting stress at which failure or instability imminent. The calculation of FS was guided by the formula: **FS (ó) =3F (L)/ 2wh2**, Where; F is the maximum load, L is the span, w is the width of the sample and h its height, the force to failure was recorded in Newton's and Strength was expressed in megapascals ***(Serhat Emre Ozkir and Yilmaz et al., 2017).***

To evaluate the fracture surfaces, Digital microscope was used to evaluate the failure pattern; two specimens from each group were selected to detect the fracture characteristics.

III. RESULTS

The normality test and flexural strength (maximum load and flexural strength) were used to present all the data. The Shapiro-Wilk and Kolmogorov-Smirnov tests were used to examine the normality data. The results showed insignificance (P value > 0.05), denoting that all data came from a normal distribution (parametric) and resembled a normal Bell curve in all groups.

Table (1) displayed the mean and standard deviation of maximum load at flexural strength for each group. The One Way ANOVA test was used to compare the groups, and the results showed a significant difference between them (P=0.005). Tukey's Post Hoc test was then used for multiple comparisons, and the results showed that Group A had the lowest significant difference (47.51 ± 8.09), Group C had the highest significant difference (58.40 ± 2.66), and Group B (50.91 ± 10.47) revealed insignificant difference with other groups.

Table (2) showed the mean and standard deviation of flexural strength for each group. The One Way ANOVA test was used to compare the groups, and the results showed a significant difference between them (P=0.003). After using Tukey's Post Hoc test for multiple comparisons, the results showed that Group A (22.61 ± 3.85), Group B (23.54 ± 4.98), and Group C (27.79 ± 1.27) were the groups with the least and most significant differences, respectively with insignificant difference between A&B groups.

Fracture characteristics of two specimens from each group:

For auto polymerized composite, Failure pattern was mixed (Adhesive failure: between housing and pick up material. and in-between pick up material and denture base material) & (Cohesive failure: in pick up material itself and in denture base itself) (Figure 4) .While, For hard reline, Failure pattern was adhesive (between pick up material and denture base), and cohesive in denture base material itself.

In Auto polymerizing acrylic resin group, Failure pattern was adhesive (between pick up material and denture base) and cohesive in denture base material.

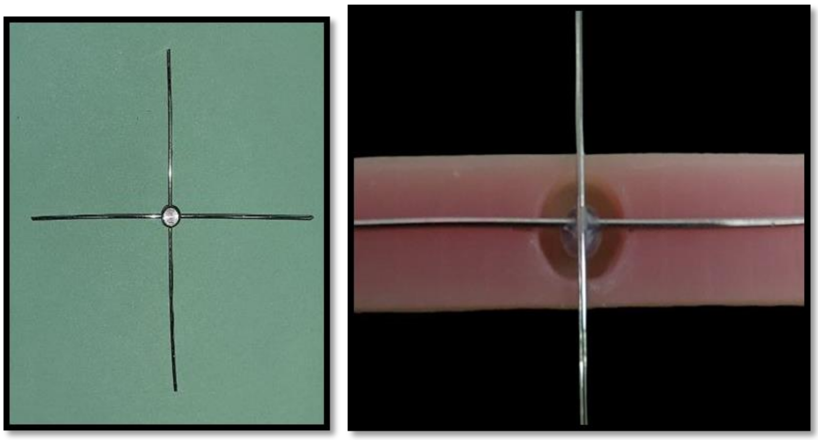

Figure 1: Centralization of metal housing prior to pick up step.

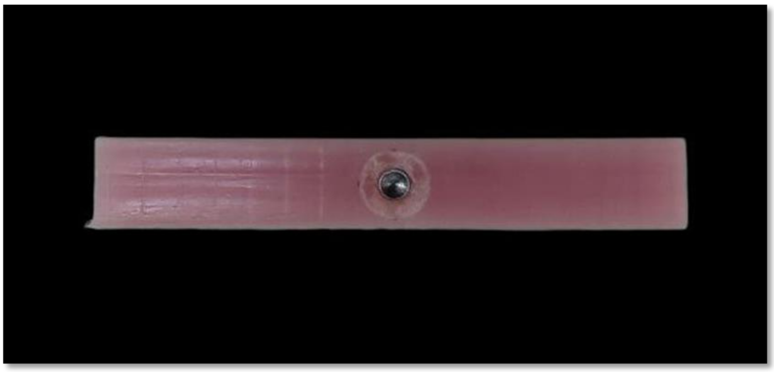

Figure 2: After removing the wire and trimming junctions.

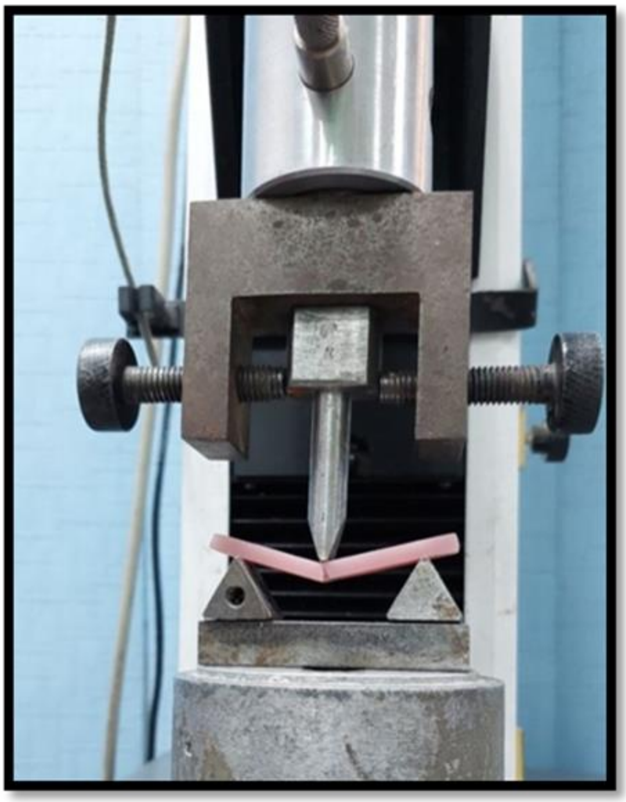

Figure 3: 3Point bending test procedure after applying load.

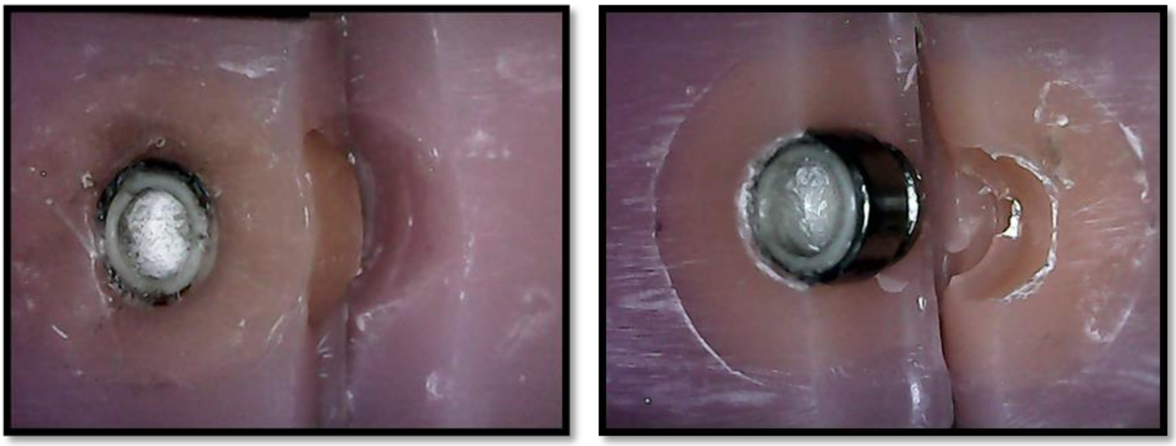

Figure 4: Mixed failure pattern (adhesive and cohesive failure).

Table (1): Mean and standard deviation of maximum load for each group, along with a comparison between them:

Max load (Mpa)	Mean	Standard deviation	P value
Auto-polymerized composite resin (lUXA pickup)	47.51 a	8.09	0.005
Group B GC Hard Reline	50.91 ab	10.47	0.005
Group C Auto-polymerized acrylic resin (APAR)	58.40 b	2.66	0.005

•*Mean denoted by the same superscript letters were insignificantly different as P>0.05.*

•*Mean denoted by different superscript letter showed a significant difference as P<0.05.*

Table (2): Mean and standard deviation of flexural strength for each group, along with a comparison between them:

Flexural strength	Mean	Standard deviation	P value
Auto-polymerized composite resin (lUXA pickup)	22.61 a	3.85	0.003
Group B GC Hard Reline	23.54 a	4.98	0.003
Group C Auto-polymerized acrylic resin (APAR)	27.79 b	1.27	0.003

• *Mean denoted by the same superscript letters were insignificantly different as P>0.05.*

•*Mean denoted by different superscript letter showed a significant difference as P<0.05.*

IV. DISCUSSION

Standardization was guaranteed as all samples were performed by single operator. Randomization was invalid because all samples were accurately inspected, and any defects in samples would be immediately discarded. Blinding was impossible except for the statistician who received the resulted data in the form of group numbers 1, 2&3 to minimize the risk of bias.

Digital workflow of overdenture samples was performed to guarantee accurate replication of all samples for standardization which is necessary for in-vitro studies Also, for decreasing in number of errors and discrepancies which is occurred in conventional technique.

To achieve maximum retention of retaining material, it is recommended that a clearance of 1.5-2mm is provided between denture base material and housing (***Baghbani et al., 2020)***. The diameter of cylindrical tube was chosen to replicate the clinical condition where Ø3.5mm in diameter and 2mm in height space was needed for housing and the additional 1.5mm space surrounding housing for pick up material ***(Baghbani et al., 2020; Serhat Emre Ozkir and Yilmaz et al., 2017)***, so the cylinder size was widened to Ø7 and 3.5mm in depth to accommodate pickup material and housing space leaving 0.5 mm of denture base material above the hollowed site, This large hollow might have a detrimental effect on the integrity of the overdenture base reducing its strength ***(Serhat Emre Ozkir and Yilmaz et al., 2017).***

Cross shape wires with centrally splinted housing was done to ensure centralization of housing within hollow during pick up for obtaining even thickness of pick up material all around for even stresses distribution.

All samples were left for 48 hours prior to testing to allow complete polymerization of resin pick up materials. Standardization of conditions is mandatory to allow comparison of reports so, to simulate oral conditions, all samples were exposed to 5000 thermal cycles between 50C -55 0C, Dwell times were 25 s in each water bath with a lag time 10 s. to mimic expected intraoral timings. This number of cycles (5000) is equivalent to 6 months clinically ***(Morresi et al., 2014).***

Flexural strength was assessed using 3point bending test for 36 blocks mimicking overdenture and divided into three equal groups.(18) (A, B, C) Letters were engraved into the samples to ensure blinding of the assessor during data collection, where letter (A) represented luxa, (B) denoted the GC reline and (C) stood for Acrostone. Each sample was statically applied compression loading until fracture. According to the study's findings, Group C had the highest values for the flexural load to failure of denture blocks (58.40 ± 2.66), while Group A had the lowest values (47.51 ± 8.09), and Group B had an insignificant difference with the other groups (50.91 ± 10.47).

Through the use of One Way ANOVA test which demonstrated a significant difference between the groups, The study's findings indicated that Group C (27.79 ± 1.27) had the highest flexural strength values when compared to Group A (22.61 ± 3.85) and Group B (23.54 ± 4.98), with insignificant difference between the A and B groups. These findings were in agreement with those of Ozkir and Yilmaz et al. which revealed that auto polymerizing PMMA groups were significantly higher than the auto polymerizing hard reline groups. However, there was insignificant difference between the remaining groups (P>.05) ***(Serhat Emre Ozkir and Yilmaz et al., 2017).***

The specimens prepared were standardized blocks which differed from the overdenture base used in clinical scenarios, However, according to ISO specifications, it was required for 3-point bending test, and the samples must be prepared in specific dimensions (64x10x4) However, the specimens' thickness was modified to account for the various clinical scenarios (***Chung et al., 2004; Serhat Emre Ozkir and Yilmaz et al., 2017).***

V. CONCLUSION:

In light of the in-vitro study's findings, the following conclusions were made:

1) The flexural strength of the 3D printed overdenture base was significantly higher when Auto polymerizing acrylic resin was used as a pick up retaining material among all group (composite-based material ”LUXA” and Hard-reline material)

2) Composite resin based material “Luxa pick up retaining material” performed similarly as hard reline material “GC Reline” concerning their effect on flexural strength of 3D Printed overdenture base materials.

Conflict of Interest:

The authors declare no conflict of interest.

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Ethics:

This study protocol was approved by the ethical committee of the faculty of dentistry-Cairo university on: 23 February 2021, approval number: 8-2-21.

Data Availability:

Data will be available upon request.

Clinical trial registration:

The protocol for this study was registered on clinicaltrials.gov, under ID: ADJC-2409-1626

Credit statement:

Author 1: Data curation, Writing - review & editing, Writing - original draft, Methodology, Conceptualization, Resources.

Author 2: Data curation, Conceptualization, Project administration, Supervision, Methodology, Writing - review & editing, Writing - original draft.

Author 3: Methodology, Writing - original draft, Writing - review & editing, Investigation, Formal analysis, Supervision, Data curation.

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