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Original article

Evaluating the Flexural Strength and Charpy Impact Strength of CAD/CAM and Compressed Molded PMMA Dentures: an *in vitro* Study

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ABSTRACT

PMMA (Polymethyl methacrylate) is a wide range of polymers are commonly used for various applications in prosthodontics. And the embedding of tooth specimens for research purposes. The unique properties of PMMA, such as its low density, aesthetics, cost-effectiveness, ease of manipulation, and tailorable physical and mechanical properties, make it a suitable and popular biomaterial for these dental applications. These complete dentures can be manufactured using two techniques: (i) conventional compression molding (CCM) technique and (ii) CAD/CAM technology. The objective of this study was to evaluate the mechanical properties of CAD/CAM PMMA denture compared to compressed molded PMMA, manufactured using the CCM technique and CAD/CAM technology. The study consisted of twenty samples, divided into two groups based on their manufacturing technique (conventional and CAD/CAM), with five samples assigned to each test. The mechanical properties of the samples were tested using flexural strength, and Charpy impact strength tests after immersing the samples in artificial saliva at 37°C for one week. The results showed that using different manufacturing techniques for PMMA CDs leads to differences in measured characteristics that affect their suitability as the only available treatment for edentulous patients. However, a statistical analysis using SSPS tools showed that the differences are not significant between the CCM technique and CAD/CAM technology. Despite the lack of statistical significance, The PMMA CDs manufactured using the CAD/CAM technology route are recommended due to their better mechanical resistance properties.

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INTRODUCTION

Loss of teeth is a matter of great concern to a majority of people and their replacement by artificial substitutes such as denture fabricated from acrylic resin, is vital to the continuance of normal life. Denture base acts as an intermediary between teeth and jaws, it must transfer all or part of masticatory forces to the sub-adjacent tissues [1]. Complete denture rehabilitation (CD) is the most common and widely used kind of prosthodontic treatment for people with edentulism. A good denture base material is biocompatible and has good physical and mechanical qualities. It should also be simple to clean and repair, with good adhesion to denture teeth [2]. Polymethyl methacrylate (PMMA) is the material of choice for denture manufacture at the moment. Dr. Walter Wright first introduced it in 1937, and it remains a popular material

due to its good working qualities [3]. Despite its great qualities, PMMA's fracture resistance might be improved [4]. Flexural strain and impact forces can cause denture fractures, which is a prevalent worry among denture users. As the alveolar ridge irregularly resorbs, the denture base has to endure uneven force distribution hence high flexural strength is critical [5]. Flexural fatigue fracture is typically explained by the formation of small cracks in a load concentration location. This form of fracture develops over time and is not caused by a single application of force, as is a fracture caused by impact. An acrylic resin's increased flexural strength assures superior fracture resistance, making it less prone to clinical failure [6]. The energy absorbed by a substance when struck by a quick blow is measured as impact strength. The denture base should ideally have a high enough impact strength to prevent fracture after accidental dropping. The method utilized to polymerize the denture base resin was discovered to be a crucial component in influencing impact strength [7]. Flexural fatigue failure may occur as a result of strong occlusal biting pressures. Failure can also occur as a result of impact force induced by dropping the denture. As a result, assessing the transverse strength and impact strength of denture base materials has been utilized to compare their performance [8].

dentures made by compression in the traditional manner shrink and warp as a result of molding. Another factor that contributes to the denture base's susceptibility to distortion and warpage is porosity. This is because porosity results in significant internal stresses [9].

The treatment of edentulous patients with prosthodontics is evolving thanks to the usage of CAD/CAM dentures. The two-appointment method used by CAD/CAM systems involves taking impressions. It is possible to complete interocclusal records and tooth selection in one visit. Therefore, CAD/CAM generated dentures provide the patient and dental professionals with a number of benefits. The pre-polymerized disc of acrylic resin used to create the CAD/CAM dentures is machined. The definitive milled prosthesis cannot shrink, contain residual monomer, or have interior porosities because this disc is manufactured under intense heat and pressure [10]. Therefore, this study aimed to evaluate in vitro a comparative evaluation of flexural strength, and Charpy impact strength for two different routes of manufacturing the PMMA material (CAD/CAM and conventional heat cure resin) techniques of the tested samples.

MATERIALS AND METHODS

Materials

PMMA denture base resin material manufactured by a different company, the material is supplied in the form of conventional and CAD. The main constituent of conventional is resin [polymer and monomer—powder and liquid, Ivoclar Vivadent, and the CAD\CAM is a PMMA discs (KINGCHR, China) of 98 mm diameter and 25 mm height were scanned in the DC5 milling system (Dental Concept Systems GmbH, Ulm, Germany) for the CAD technique.

Samples Preparation

These denture PMMA materials were manufactured in two different routes (conventional and CAD) according to the manufacturer's instructions. twenty samples, divided into two groups based on their manufacturing technique (conventional and CAD/CAM), with seven samples assigned to each test. The mechanical properties of the samples were tested using flexural strength and Charpy impact strength tests after immersing the samples in artificial saliva at 37°C for one week. Samples were fabrication with the dimension (65 x 10 x 3) mm.

Compression molded manufacturing technique

Samples fabricated by the lost wax technique performed by modeling wax strips measuring (65 x 10 x 3) mm, were cut using a wax knife the measurements of all wax strips must be verified and that they conform to the required measurements and at the same time the flask was prepared the improved type of gypsum was mixed according to the manufacturer's instructions. The flask was placed in a water bath for 8 minutes, separated, and the wax was washed with hot water. A final rinse was done with clean water and the halves were left to cool to room temperature.

The flask was placed in a water bath for 8 minutes, separated, and the wax was washed with hot water. A final rinse was done with clean water and the halves were left to cool to room temperature. Ivoclar Vivadent resin, at a ratio of 21g polymer to 10 ml monomer, is mixed to ensure the wetting of all polymer particles .The bowl was covered for (10 minutes) until the mixture reached the filling stage (dough). The resin was condensed in the mold with finger pressure.the flask was sealed in a pneumatic Flaskpress (Coe-Bilt) under 6,000 psi pressure. The flask was then placed in boiling water for 30 minutes per the manufacturer's instructions. The flask was left to cool for 30 minutes and then the flask was immersed in water for 15 minutes before emptying.

After making sure that the flask has reached room temperature, it is opened and the resin samples were taken out. The whole samples is hand-polished for removing any voids or gross irregularities and finshed by after that, the samples were finished and polished final dimension of all samples should be (65 x 10 x 3) mm measured with a digital caliper

(Neiko) at 5 points to ± 03 mm. All samples were stored in distilled water at room temperature for a week for conditioning, according to manufacturers' instructions and recommendations.

CAD/CAM manufacturing technique

The resin discs (KINGCH^{R}, China) of 98 mm diameter and 25 mm height were installed inside the milling system (Vhf K5, India). The layout of the strip of (65 × 10 × 3) mm dimensions was cutting by lathing machine. All specimens were polished with a 400-grit silicon carbide abrasive paper under running water. Sequential sandpapering using micromotor and handpiece with mandrel was done with 5000 rpm for 90 sec. for finishing. Polishing was done by buffing with pumice slurry. After polishing, all specimens were checked for their dimensions with a digital caliper.

Artificial Saliva Preparation and Immersion Protocol

Fresh artificial saliva solution was formulated by mixing NaCl 0.400 g, KCl 0.400 g, $NaH_2PO4.H_2O$ 0.69 g, $CaCl_2$.H2O 0.795 g, and Na2S.9H_2O 0.005 g in 1,000 mL of deionized water (as proposed by Fusayama et al) [11]. The pH of freshly synthesized saliva was 5.3 to 5.5. The pH was then adjusted to the study desired pH values, a separate glass container was used with a plastic lid.

All samples were stored in artificial saliva of at 37°C for 7 days to simulate the daily patient use of dentures. Samples were in glass bottles to ensure that all samples were surrounded by the solutions in all aspects. All specimens were tested for flexural strength and Charpy impact strength after 7 days' immersion. The artificial saliva Preparation and Immersion Protocol.

Flexural Strength Test

Samples were tested using a three-point was conducted on five samples of each group of the PMMA material subjected to after immersing the samples in artificial saliva at 37°C for one week. tested PMMA. Samples were cut with the dimension (65x10x3) mm, following the Manufacturer's instructions and recommendations. using the standard relation according to the international standard ISO 20795-1 the specimen was mounted on the designed part of a WP300 materials Testing Machine,20KN-GUNT Hamburg (three-point loading and testing equipment). The load was applied on the center of the specimen with a crosshead speed of 0.5 mm /min. The maximum load before fracture was measured. The flexural strength of the specimens was calculated using the standard relation:

$$S = 3LP / 2WT2$$

Where: S = Flexural strength. P = Maximum load before fracture. L = Distance between supports (50 mm). W = Width of the specimen (10 mm). T = Depth (thickness) of the specimen (2.5 mm), which were randomly made of each sample. The data collected and the mean of seven PMMA samples of each group was measured (Conventual, CAD), calculated and analyzed using suitable statistical methods.

Charpy Impact Strength Test

Charpy impact strength test was conducted on five samples of each group of the PMMA material subjected to after immersing the samples in artificial saliva at 37°C for one week carried out using (CEAST Resil Impactor tester) at room temperature with impact energy of 15 J. The specimens for impact test were prepared and notched according to (D256-10). A minimum of seven specimens were taken and the average was calculated.

The data collected and the mean of seven PMMA samples of each group was measured (Conventual, CAD), calculated and analyzed using suitable statistical method.

Statistical Analysis

Parametric tests such as analysis of variance (t-test) is potentially used since the study is designed to look at the impact of only one independent variable on the selected dependable variables, independent sample t-test is carried out to see if there are any significant differences in the means for two groups in the (dependent) variable of interest.

RESULTS

Flexural Strength Result

The mean value for condition of the PMMA CAD / CAM was 108.28, and the mean for condition of the PMMA Conventional is 60.57. The standard deviation for PMMA CAD / CAM is 6.44 and for PMMA Conventional was 4.89. The number of cases in each condition (N) was 7 in figure (1) at p = 0.000 graph displays more clarifications about the result of differences.

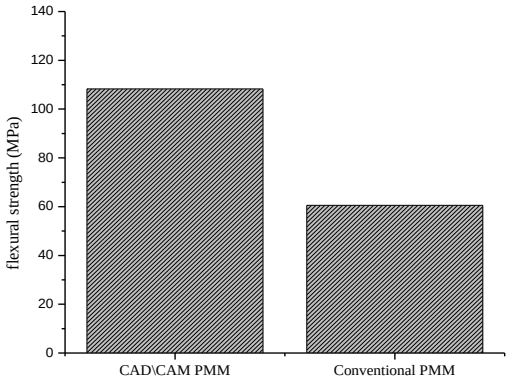

Fig. 1. Comparison between the flexural strength (MPa) of the tested

Charpy Impact Strength Test Result

The mean value for condition of the PMMA CAD\CAM was 27.71, and the mean for condition of the PMMA conventional was 2.54. The standard deviation for PMMA CAD\CAM is 3.25 and for PMMA Conventional is 0.26. The number of cases in each condition (N) was 7 in figure (2) at p = 0.000 graph displays more clarifications about the result of differences.

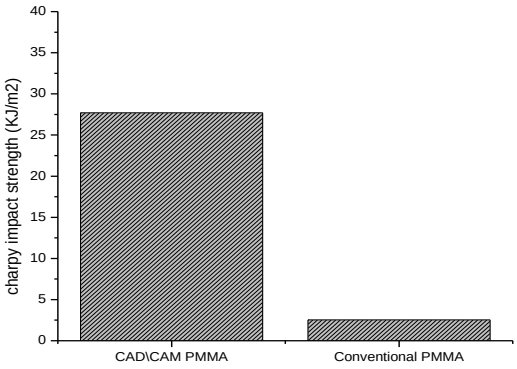

Fig. 2. Comparison between the Charpy impact strength (KJ/m2) of the tested

DISCUSSION

Most individuals are quite concerned about losing their teeth, and maintaining a normal life requires replacing lost teeth with artificial ones, like dentures made of acrylic resin [12]. Restoring the whole dentition and related components with a removable prosthesis made of acrylic is one of the most popular and affordable treatment options for all edentulism [13]. Due to its low density, stainability, low cost, ease of handling, dimensional stability in oral situations, and biocompatibility, polymethyl methacrylate resin is the most widely used denture base material. However, it has some drawbacks, especially regarding flexural and impact strength. The cause of flexural failure in the mouth is the flexing of the base resin of the denture, which results in uneven support for the tissue-borne prosthesis over time due to the progressive, continuous, and irregular resorption of alveolar bone. A fall or accident is the cause of impact failure outside the mouth [14]. Therefore, this study primarily focused on the comparison of flexural and impact strengths of the CAD/CAM, and conventional compression molded denture base materials [15].

The mean flexural strength was recorded with a universal testing machine. Three-point bending test is a routinely used and widely accepted test for assessment of flexural properties, according to the international standards for polymer materials and ISO 20795-1 for denture base polymers. The standard states that a minimum of 65 MPa is the desired flexural strength of denture acrylics [16]. By using that criterion in our study, all groups in the present study have acceptable flexural properties for clinical use. The mean impact strength in this study was recorded with Charpy impact tester for the two test groups. Impact strength data and fracture characteristics depend upon many factors including material selection, the geometry of the specimen, fabrication variables, stress concentrations, and position of specimen

and temperature. Stress concentration are the main contributors to impact failure in dentures which include notches, cuts, depressions, sharp corners and grooves, rough or textured surfaces, or inclusion of foreign particles [17].
The observations of this study were also in agreement with Aguirre et al. and Al-Dwairi et al., who also found superior flexural and impact properties of the CAD/CAM resins compared to the conventional technique [15,18] The latter concluded that the CAD/CAM PMMA is more durable, as confirmed by scanning electron microscopy [18]. Various reasons can be put forth for the differences in results of test samples such as residual monomer content, degree of conversion/polymerization, particle size, density, chemical nature of the polymer, etc. The residual monomer can influence the flexural strength of denture bases due to its plasticizing properties [19].
The higher flexural and impact strength values of the CAD/ CAM samples in the present study may be correlated to the higher degree of polymerization, which is one of the major factors determining resin strength. Since, the CAD/CAM resin blocks are pre-polymerized to a very high degree using equipment more sophisticated than conventional methods, a highly condensed resin mass with minimal porosities is achieved [20].
The current study clearly shows that the CAD/CAM denture bases have the highest flexural and impact strength of all test groups. Their clinical performance should provide an edge over all the other denture base materials and should be a clinician's first choice of material and processing technique for denture fabrication. However, the assessment of maxillomandibular relationships with CAD/CAM dentures is compromised. Also, the laboratory setup expenditure and feasibility are still a challenge in our daily practice. Some of these disadvantages may necessitate remaking the complete denture at a cost of additional time and expense [21].
The limitations of the current study were the in vitro nature of the study and the samples prepared do not replicate the shape of an actual denture.

CONCLUSION

The results showed that PMMA CAD\CAM manufacturing method had greater effect on the mechanical flexural strength and mechanical Charpy impact strength properties and provided a higher degree of safety, which comply with the finishing and polishing were done with protocols.

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Conflict of interest. Nil

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تقييم قوة الانحناء وقوة تأثير تشاربي لأطقم الأسنان المصنوعة بتقنية CAD/CAM والأطقم المصبوبة بالضغط من: PMMA دراسة مخبرية

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المستخلص

البولي ميثيل ميثاكريلات هو مجموعة واسعة من البوليمرات التي تُستخدم عادةً في تطبيقات مختلفة في طب الأسنان التعويضي. الخصائص الفريدة للبولي ميثيل ميثاكريلات مثل كثافتها المنخفضة، وجمالها، والتكلفة المالية، وسهولة التعامل معها، وكذلك الخصائص الفيزيائية والميكانيكية القابلة للتخصيص، تجعلها مادة حيوية مناسبة وشائعة لهذه التطبيقات السنية. يمكن تصنيع هذه الأطقم الكاملة باستخدام تقنيتين: (i)تقنية التشكيل بالضغط التقليدي (CCM) و (ii) تقنية CAD/CAM. الهدف من هذه الدراسة هو تقييم الخصائص الميكانيكية لطقم الأسنان المصنوعة من البولي ميثيل ميثاكريلات بتقنية CAD/CAM مقارنةً بطقم الأسنان المصنوعة من البولي ميثيل ميثاكريلات بتقنية الضغط التقليدي، وتقنية.CAD/CAM شملت الدراسة عشرين عينة، مقسمة إلى مجموعتين بناءً على تقنية التصنيع التقليدية و(CAD/CAM)، مع تخصيص خمس عينات لكل اختبار. تم اختبار الخصائص الميكانيكية للعينات باستخدام اختبارات "قوة الانحناء" واختبارات قوة الصدمة "شاربي" بعد غمر العينات في اللعاب الصناعي عند 37 درجة مئوية لمدة أسبوع. تشير النتائج إلى أن استخدام تقنيات تصنيع مختلفة لأقراص PMMA يؤدي إلى اختلافات في الخصائص المقاسة التي تؤثر على ملاءمتها كعلاج متاح وحيد للمرضى فاقدي الأسنان. ومع ذلك، أظهرت التحليلات الإحصائية باستخدام أدوات SSPS أن الفروقات ليست ذات دلالة إحصائية بين تقنية CCM تكنولوجيا CAD/CAM على الرغم من عدم وجود دلالة إحصائية. يُوصى بأقراص PMMA المصنعة باستخدام تقنية CAD/CAM بسبب خصائص مقاومتها الميكانيكية الأفضل .

الكلمات الدالة. بولي ميثيل ميثاكريلات، CAD/CAM، التشكيل بالضغط التقليدي، طقم الأسنان، قوة الانحناء، قوة تأثير شاربي.