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Comparative Evaluation Of Accuracy And Impact Strength Of Maxillary Complete Denture Base Fabricated By Conventional, Injection Moulding, And 3d Printing Technique- An In Vitro Study

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1. INTRODUCTION

Complete dentures have a rich history that dates back thousands of years. The earliest known attempts at tooth replacement can be traced to the Etruscans around 630 BCE, who used gold bands to support missing teeth[1]. The development of modern complete dentures gained significant momentum in the 18th and 19th centuries, driven by advancements in dental materials and techniques. Today, complete dentures are meticulously designed prosthetic devices that restore both oral function and aesthetics for individuals who have lost all their natural teeth in one or both arches.[2]

The significance of complete dentures goes beyond simple tooth replacement. They play a crucial role in restoring masticatory function, allowing individuals to chew and digest food effectively. Additionally, complete dentures help maintain facial structure by providing support to the lips and cheeks, preventing the sunken appearance commonly associated with tooth loss.[3] Beyond these physical benefits, dentures contribute to psychological well-being by improving speech, self-confidence, and social interactions. With continuous advancements in prosthodontics and dental materials, modern complete dentures offer enhanced comfort, stability, and aesthetics, greatly improving the quality of life for edentulous patients.[4]

Over the years, various materials have been used to fabricate complete dentures, evolving alongside advancements in dental technology. Early dentures were crafted from materials such as ivory, bone, and even human or animal teeth.[5] As dentistry progressed, acrylic resins became the standard due to their durability, ease of fabrication, and aesthetic appeal. Polymethyl methacrylate (PMMA) emerged as the most widely used denture base material, offering good strength and adaptability. More recently, materials such as nylon-based flexible resins and high-impact acrylics have been introduced to enhance comfort and longevity. [6]

Among modern denture base materials, Lucitone stands out for its superior properties. Lucitone 199, a high-impact acrylic resin, is widely recognized for its exceptional strength, fracture resistance, and aesthetic qualities.[7] It offers balanced translucency and lifelike vein simulation, ensuring a natural appearance. Additionally, Lucitone HIPA (High Impact Pour Acrylic) provides enhanced durability, reducing the risk of fractures and improving patient satisfaction.[8] Its ability to withstand stress and resist breakage makes it a preferred choice for both tissue-supported and implant-supported dentures. With its proven clinical success and reliability, Lucitone continues to set the industry standard for premium denture base materials.[9]

While the choice of denture material is crucial, the processing method used to fabricate the denture significantly impacts its strength, accuracy, and longevity. Advanced techniques such as injection molding, 3D printing, and milling have enhanced precision, minimized errors, and improved the overall fit, ensuring superior functional and aesthetic outcomes for patients.[10]

For many years, the lost wax technique was the gold standard for fabricating complete dentures. This conventional method involved creating a wax model of the denture, investing it in a mold, and then replacing the wax with acrylic resin through a heat-curing process.[11] While effective, this technique was labor-intensive, required multiple steps, and was prone to polymerization shrinkage, leading to minor inaccuracies in fit. Despite its limitations, the lost wax technique remained widely used due to its reliability and ability to produce functional dentures with acceptable aesthetics.[12]

In the last two decades, computer-aided design (CAD) and computer-aided manufacturing (CAM) technology have been widely adopted in the dental field for manufacturing various prostheses due to their advantages, such as increased efficiency, automation, and precision.[13] The fabrication of complete dentures using CAD/CAM technology has evolved with the development of digital devices and specialized CAD software. Maeda et al. reported the first scientific study describing the CAD/CAM procedure for fabricating a complete denture. The digital workflow begins with scanning the edentulous arch, including challenging areas that intraoral scanners find difficult to capture, such as non-keratinized tissue and smooth surfaces covered with saliva.[14]

Advancements in dental technology have revolutionized the process of complete denture manufacturing. Injection molding is one such technique that enhances the accuracy and strength of denture bases. This method involves injecting thermoplastic or high-impact acrylic resin into a mold under pressure, reducing porosity and improving the overall durability of the denture. Injection molding ensures more uniform material distribution, leading to better adaptation to the underlying tissues and improved patient comfort.[15,16]

3D printing has emerged as a groundbreaking innovation in prosthodontics, allowing for precise digital design and fabrication of dentures. Using CAD/CAM technology, dentures can be designed virtually and printed layer by layer with biocompatible resins. This technique significantly reduces fabrication time, minimizes human errors, and allows for easy replication of dentures when needed. Additionally, 3D printing enables customization of denture designs, ensuring optimal fit and aesthetics tailored to individual patient needs.[17]

Milling, another advanced technique, involves carving dentures from pre-polymerized acrylic blocks using computer-controlled milling machines. This method eliminates polymerization shrinkage and enhances the strength and accuracy of the final prosthesis. Milled dentures exhibit superior fit, reduced processing errors, and enhanced longevity compared to conventionally fabricated dentures.[18] The integration of digital workflows in denture fabrication has streamlined the process, improving efficiency, precision, and overall patient satisfaction. As technology continues to evolve, these modern techniques are setting new standards in prosthodontics, ensuring better functional and aesthetic outcomes for edentulous patients.[19]

The success of complete dentures relies on several key properties, including accuracy, fit, impact strength, flexural strength, and wear resistance. Each of these factors plays a crucial role in ensuring the functionality and longevity of the prosthesis. A well-fitting denture enhances comfort and stability, while flexural strength ensures the material can withstand repeated stress without deformation. Additionally, wear resistance helps maintain the integrity of the denture over time, preventing excessive deterioration. Among these properties, accuracy and impact strength are particularly significant in achieving a successful treatment outcome.[20]

Accuracy in denture fabrication is essential for achieving a precise fit, which directly influences patient comfort and overall functionality. A well-adapted denture minimizes tissue irritation, enhances mastication efficiency, and prevents common issues such as sore spots or discomfort. Proper adaptation to the underlying oral structures ensures that the denture remains secure during speech and chewing, significantly improving the patient's experience. Advanced fabrication techniques, such as CAD/CAM milling and 3D printing, have greatly improved the precision of dentures, reducing errors and enhancing the overall fit.[21]

Impact strength is equally critical, as dentures are subjected to various forces during daily use. A denture with high impact strength can withstand accidental drops or sudden occlusal forces without fracturing, ensuring longevity and durability. This property is particularly important for edentulous patients who rely entirely on their prosthesis for oral function. Materials with superior impact resistance, such as high-impact acrylics, enhance the structural integrity of the denture, reducing the risk of breakage and the need for frequent repairs. By prioritizing accuracy and impact strength in denture fabrication, clinicians can provide patients with prostheses that offer both functional reliability and long-term durability, ultimately improving their quality of life.[22]

This study aims to compare the accuracy and impact strength of complete dentures fabricated using three distinct processing methods: conventional heat-cured technique, 3D printing, and injection molding. Each method offers unique advantages in terms of material adaptation, structural integrity, and resistance to functional stresses. By evaluating these key properties, the study seeks to determine which processing technique provides superior denture performance, ensuring optimal fit, durability, and patient satisfaction.

Methodology

2. MATERIALS AND METHODS

Aim:

To evaluate and compare the accuracy and impact strength of maxillary denture bases fabricated by Conventional, Milling, and 3D printing techniques.

Objectives:

To evaluate the accuracy and impact strength in maxillary complete denture bases fabricated by the Conventional Technique.

To evaluate the accuracy and impact strength in maxillary complete denture bases fabricated by the 3D Printing Technique.

To evaluate the accuracy and impact strength in maxillary complete denture bases fabricated by the Injection Molding Technique.

To determine the best technique for evaluating accuracy and impact strength.

Materials

The materials used in this study are as follows:

Lucitone 199 Polymethylmethacrylate Powder (Dentsply Sirona)

Lucitone 199 Polymethylmethacrylate Liquid (Dentsply Sirona)

Customized Three-Unit Stainless Steel Molds

Heat Cure Processing Unit (Model C-73, Unident Dental Equipment Ltd., India)

Acrylic Trimming Lathe

Rough and Smooth Sandpaper (120 and 1000 grit, John Oakey and Mohan Ltd.)

Pumice Powder (Wet Polishing, BK Jagan and Co)

Rouge (Dry Polishing, BK Jagan and Co)

Polishing Buff (Swisso)

Izod Impact Tester (International Equipment India)

3D Printing Resin Ackuretta

3D Printer (ELEGOO)

Injection Molding Flask

Data Matching Software

Methods

Preparation of Samples:

a. Conventional Technique

Five specimens were fabricated using Lucitone 199 denture base material (high-impact material) within a three-unit customized mold.

The mold dimensions for impact strength testing adhered to ISO 1567:1999 standards, measuring **50mm × 6mm × 4mm**.

The Lucitone 199 polymer powder and monomer liquid were measured in a 3cc:1ml ratio following manufacturer instructions.

The powder and liquid were transferred into a silicone cup and stirred thoroughly for 15 seconds until a dough-like consistency was achieved.

The mixture was kneaded and placed into the cavity of the stainless steel mold.

The counter portion of the mold was positioned, and the screws were tightened using a hand torque (Allen key), followed by flash removal.

The mold was subjected to bench curing for 30 minutes, then heat-cured in a water bath using an acrylic curing unit (Model C-73, Unident Dental Equipment Ltd., India).

Polymerization was achieved via a short curing cycle: 73°C for 1.5 hours, followed by 100°C for 0.5 hours.

After cooling, the specimens were deflasked, trimmed, and finished.

Excess material was trimmed using an acrylic trimming lathe, followed by precision trimming with a Tungsten-carbide bur.

Surface finishing was performed using sandpaper starting from 120-grit, followed by 1000-grit sandpaper.

The specimens were polished using wet pumice powder and dry polishing with rouge on a polishing buff.

b. Injection Molding Technique

Lucitone denture base polymer and monomer were measured as per manufacturer guidelines.

The mold cavity was cleaned, dried, and coated with a mold release agent for easy specimen removal.

The polymer and monomer were mixed to achieve a uniform dough-like consistency.

The prepared material was injected into the mold cavity under controlled pressure for even distribution.

The mold was cured using a stepwise temperature protocol for complete polymerization.

The mold was cooled gradually before retrieving the specimens to avoid warping.

Excess material was trimmed using a Tungsten-carbide bur, followed by sanding with 120-grit and 1000-grit sandpaper.

Wet polishing with pumice powder was done, followed by dry polishing with rouge on a buffing wheel.

The specimens were inspected for dimensional accuracy and visual quality.

c. 3D Printing Technique

A 3D model of the specimen was designed using CAD software, ensuring precise dimensions and structural integrity.

The design file was converted into a compatible format (STL or OBJ) for the Shining 3D printer.

The Ackuretta 3D resin was loaded into the printer's resin tank.

Printing parameters, such as layer thickness, exposure time, and print speed, were adjusted for optimal curing.

The Shining 3D printer performed layer-by-layer photopolymerization, curing each layer with UV light.

After printing, the specimens were carefully removed from the build plate.

The specimens underwent post-processing by cleaning in an isopropyl alcohol bath to remove excess resin.

Post-curing was performed using a UV curing chamber to enhance mechanical strength.

Support structures were trimmed, and the surface was polished to a smooth finish.

Final inspection ensured dimensional accuracy and material consistency.

Testing of Samples:

a. Impact Strength Testing

Impact strength was measured using the Izod Impact testing machine.

A notched sample with a V-shaped groove (1.2mm deep) was used for testing.

The sample dimensions were: **Thickness: 4mm, Width: 6mm, Length: 50mm**.

The notch was pre-formed in the mold to meet the testing criteria.

The specimen was positioned in the machine, and the hammer (pendulum) was securely locked in place.

The hammer was released to fracture the specimen, and the energy absorbed by the sample was recorded.

If the specimen did not fracture with the original hammer, a heavier hammer was used.

Impact strength was calculated by dividing the fracture energy by the specimen's thickness.

b. Accuracy Testing

Fifteen specimens were scanned using the Shining 3D lab scanner: five each from 3D printing, injection molding, and conventional techniques.

The STL data of the tissue surface of the master model and the intaglio surface of the complete denture (CD) base were superimposed using a best-fit alignment method.

The accuracy of three specific regions — the residual ridge, palate, and denture border — was evaluated.

The deviation between the superimposed surfaces of the CD base was analyzed using data-matching software.

The mean positive and negative deviations were calculated to quantify trueness.

The square root of the arithmetic mean of squared deviation values was used to assess accuracy.

This methodology ensures a comprehensive evaluation of the accuracy and impact strength of complete denture bases fabricated using three different techniques, allowing for a thorough comparison of their performance.

The impact strength of denture base resins fabricated using three different processing methods—3D printing (Group I), conventional heat-cured processing (Group II), and injection molding (Group III)—was evaluated using an Izod impact tester. The results demonstrated that Group I (3D printed) exhibited the highest mean impact strength at 0.31

± 0.05 J, followed by Group III (injection molded) with a mean value of 0.22 ± 0.05 J. Group II (conventionally processed) showed the lowest impact strength, averaging 0.19 ±

0.03 J. These findings suggest that the 3D printing technique yields superior impact resistance in denture base resins compared to traditional and injection molding methods. The improved performance of 3D printed resins may be attributed to differences in material composition and layer-by-layer fabrication, which potentially enhance structural integrity.

The accuracy of denture base resins fabricated using three different processing methods— 3D printing (Group I), conventional heat-cured processing (Group II), and injection molding (Group III)—was assessed through STL file superimposition using best-fit alignment in data matching software. The evaluation revealed that Group I (3D printed) exhibited the highest mean accuracy with a value of 0.51 ± 0.05 mm, followed by Group II (conventional) at 0.33 ± 0.03 mm, and Group III (injection molded) at 0.30 ± 0.05 mm. These results indicate that the 3D printed dentures demonstrated superior dimensional accuracy compared to the other two techniques. The enhanced accuracy in the 3D printed group may be attributed to the precision of additive manufacturing and its ability to minimize processing distortions.

Statistical analysis

Data entry was performed using Microsoft Excel, and normality was assessed via Kolmogorov-Smirnov and Shapiro-Wilk tests, both indicating p>0.05. Descriptive statistics, including mean and standard deviation (SD), were analyzed, with categorical data evaluated using the chi-square test. Intragroup comparisons were conducted using the paired t-test, while intergroup differences were assessed using the unpaired t-test, with p<0.05 considered statistically significant. All statistical analyses were performed using SPSS software version 25.0.

Test for Normality

To assess the normality of the data distribution, both the Kolmogorov-Smirnov and Shapiro-Wilk tests were applied, with a significance threshold (p-value or alpha) set at 0.05, as presented in Table 1 below. It was seen that the value of both kolmogorov - smirnov test and shapiro - wilk test is > 0.05, which means that the data is normally distributed over the given parameters from the sample.

Values Kolmogorov-Smirnova

Shapiro-Wilk

Table 1: showing data distribution normality statistics

Values	**Kolmogorov-Smirnov[a]**			**Shapiro-Wilk**		
	Statistic	**Df**	**Sig.**	**Statistic**	**df**	**Sig.**

Group A	**.219**	**28**	**.001**	**.887**	**28**	**.0010**
Group B	**.149**	**28**	**.113**	**.909**	**28**	**.019**
Group C	**.140**	**28**	**.1109**	**.920**	**28**	**.034**

The distribution of the data was also observed for all the given parameters through histograms and normal Q-Q plot and through error bars. For all the parameters, it was seen that the mid points of histograms as shown in figure 3 below for all parameters when joined, forms a linear line of normal distribution with no presence of kurtosis and skewness or no deviation of data to the extremes were evident.

Figure 3: showing normality data distribution through histogram

The parameters' mean values remained stable without significant deviations, and the standard deviation values were minimal. As illustrated in Figure 4, the Q-Q plot confirms that the sample data closely aligns with the expected distribution curve, showing negligible divergence from the anticipated values.

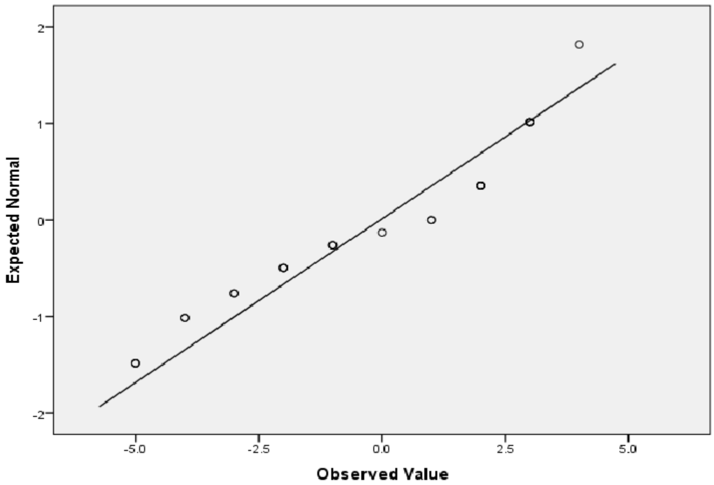

Figure 4: showing normality data distribution through Q-Q plot

Figure 5 illustrates that the error bars for all parameters exhibit minimal variance, with the median values remaining stable. There is no significant deviation towards the upper (25th percentile) or lower (75th percentile), indicating consistent distribution across the dataset.

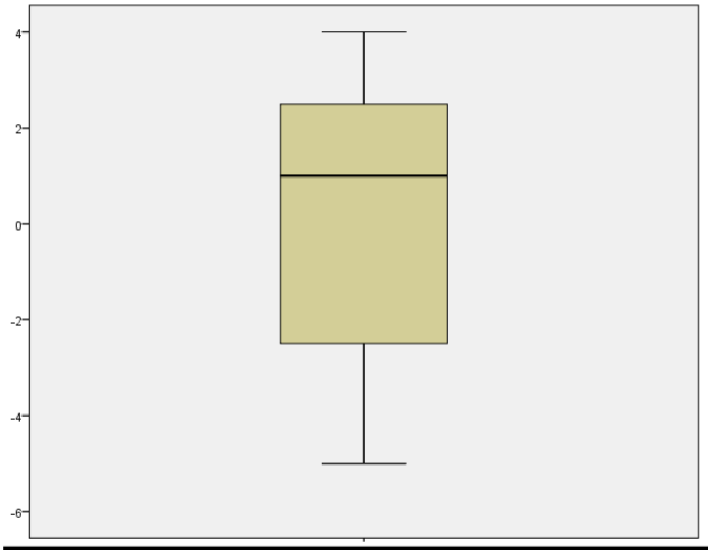

Figure 5: showing normality data distribution through error bar diagram

Impact strength

Table: Mean Impact strength under compressive load (kN) of Group I, II, III

Impact strength			
Groups evaluated	N	Mean	Std. Deviation
Group I (3D printing)	10	0.31	0.05
Group II (Conventional technique)	10	0.19	0.03
Group III (Injection moulding)	10	0.22	0.05

Mean Impact strength of Group I was 0.31 ± 0.05, in Group II was 0.19 ± 0.03 while in Group III the Impact strength was 0.22 ± 0.05 respectively.

Table: Comparison of Impact strength under compressive load (kN) of Group I, II, III

ANOVA		
Impact strength		
	F	p value
Between Groups	21. 673	<0.001*

ANOVA for between group comparison of Impact strength under compressive load (kN) of Group I, II, III showed statistically significant difference in the overall Impact strength between Group I, II, III respectively

Table: Pairwise comparison of Impact strength under compressive load (kN) of Group I, II, III

(I) Group	(J) Group	Mean Difference (I-J)	p value
Group I	Group II	0.12	<0.05*
	Group III	0.09	<0.05*
Group II	Group I	-0.12	<0.05*
	Group III	-0.03	>0.05
Group III	Group I	-0.09	<0.05*
	Group II	0.03	>0.05

*. The mean difference is significant at the 0.05 level.

Pair wise comparison was done using Tukey's post hoc test showed statistically high significant difference when Group 1 was compared with Group 2 and 3 respectively. ($p<0.05$*) A statistically significant difference in Impact strength was observed when Group II and III was compared with Group I respectively. ($p<0.001$**)

There was no statistically significant difference between II and III and in between Group II and III in the overall Impact strength under compressive load. ($p>0.05$)

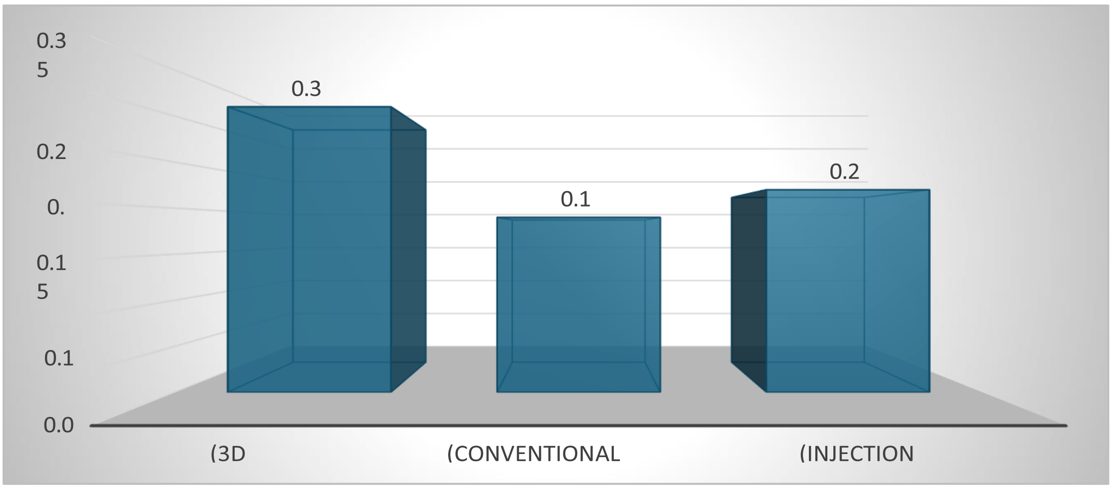

Figure: showing overall Impact strength under compressive load (kN)

Accuracy

Table: Mean Accuracy of Group I, II, III

Accuracy			
Groups evaluated	N	Mean	Std. Deviation
Group I (3D printing)	10	0.51	0.08
Group II (Conventional technique)	10	0.33	0.12
Group III (Injection moulding)	10	0.30	0.17

Mean Impact strength of Group I was 0.51 ± 0.08, in Group II was 0.33 ± 0.12 while in Group III the Accuracy was 0.30 ± 0.17 respectively.

Table: Comparison of Accuracy between Group I, II, III

ANOVA		
Accuracy		
	F	p value
Between Groups	13.54	<0.001*

ANOVA for between group comparison of Accuracy under compressive load (kN) of Group I, II, III showed statistically significant difference in the overall Accuracy between Group I, II, III respectively.

Table: Pairwise comparison of Accuracy of Group I, II, III

(I) Group	(J) Group	Mean Difference (I-J)	p value
Group I	Group II	0.18	<0.05*
	Group III	0.21	<0.05*
Group II	Group I	-0.18	<0.05*
	Group III	0.03	>0.05
	Group I	-0.21	<0.05*

Group III	Group II	-003	>0.05

*. The mean difference is significant at the 0.05 level.

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There was no statistically significant difference between II and III and in between Group II and III in the overall Accuracy under compressive load. ($p>0.05$)

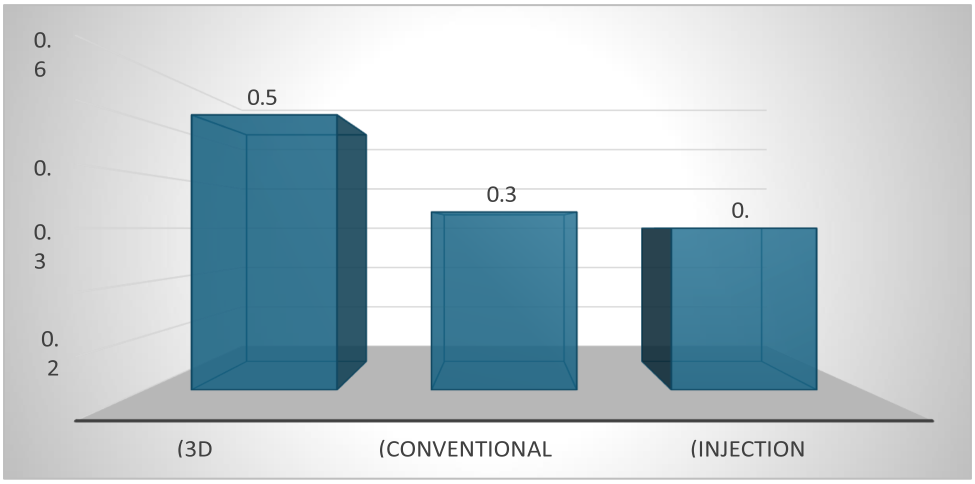

Figure: showing overall mean Accuracy

3. DISCUSSION

Denture base materials have undergone significant advancements since the 18th century, with continuous improvements in durability, aesthetics, and mechanical strength. Over time, innovations in material science have enhanced the functionality and longevity of denture bases. Today, in the 21st century, polymethyl methacrylate (PMMA) is widely recognized as the standard material for denture bases. PMMA, derived from methacrylic acid or acrylic acid, is supplied as a two-part system consisting of liquid and powder.[22] When mixed, these components form a dough-like consistency suitable for molding. Its polymerization can be initiated through heat, chemicals, or light, with heat- activated PMMA being the preferred choice due to its superior strength compared to cold-cure PMMA. This material is favored for its ease of use, moldability, lightweight properties, and affordability, making it a staple in dental applications.[23]

Despite its advantages, denture base fractures remain a common challenge in prosthodontics. To address this issue, high-impact strength resins were introduced, offering improved durability and fracture resistance. During repetitive loading, such as chewing, stress concentrations lead to the formation and propagation of microcracks within the material.[24] Over time, these microcracks grow, eventually leading to prosthesis failure. The mechanisms of fracture can be categorized into three types: mixed fractures, brittle fractures, and ductile fractures. Mixed fractures exhibit characteristics of both brittle and ductile

failures.[25] Brittle fractures primarily occur due to cleavage, where cracks propagate

along specific crystallographic planes, leading to sudden failure. Ductile fractures involve micro-void coalescence, where voids form and expand under applied forces until the material ultimately fractures.[26]

Materials that undergo brittle fractures tend to experience minimal plastic deformation before breaking, resulting in significantly lower impact strength. Cleavage-induced fractures occur almost instantaneously once a crack initiates, making it a common mechanical failure in brittle materials. Given these limitations, researchers continue to refine denture base materials by enhancing their impact resistance and durability. Advancements in material science are focused on improving mechanical properties, ensuring longer-lasting and more reliable prosthetic solutions for dental patients. Through ongoing research and innovation, modern denture bases are becoming increasingly resilient, capable of withstanding daily functional stress while maintaining their structural integrity.[27,28]

Early complete denture fabrication relied on materials such as vulcanized rubber, ivory, and metals like gold and silver. In the late 19th and early 20th centuries, acrylic resins, particularly polymethyl methacrylate (PMMA), became the standard due to their improved aesthetics, durability, and ease of processing. PMMA quickly replaced previous materials as it allowed for greater precision, better fit, and cost-effectiveness, making it a preferred choice in prosthodontics. [29]

Lucitone denture base material, a high-impact PMMA, further advanced the field by offering superior fracture resistance, flexibility, and enhanced aesthetic properties. It is particularly known for its high toughness, resilience to mechanical stress, and color stability, ensuring long-term durability and patient comfort. Lucitone materials also exhibit low water absorption, minimizing dimensional changes over time and enhancing longevity. Due to these characteristics, Lucitone is widely used in conventional and injection-molded denture fabrication, providing reliable clinical outcomes and improved prosthesis strength compared to standard PMMA.[30]

With advancements in digital dentistry, 3D-printed resins have revolutionized denture fabrication by introducing high-precision, customizable workflows. These resins provide consistent layer-by-layer accuracy, enabling better adaptation to patient-specific anatomical structures. 3D printing reduces material wastage, shortens production time, and ensures repeatability, making it an efficient alternative to traditional methods. While these resins offer improved detail resolution, certain limitations such as brittleness, post- processing requirements, and resin stability still pose challenges. However, ongoing research continues to enhance mechanical properties, biocompatibility, and strength, making 3D-printed dentures a promising solution for modern prosthodontics.[31-32]

The transition from conventional materials to Lucitone denture base materials and 3D-printed resins reflects the ongoing pursuit of durability, precision, and efficiency in denture fabrication. While Lucitone remains a gold standard in traditional denture processing, 3D printing offers a forward-looking approach with potential for even greater personalization and clinical accuracy. The future of denture fabrication lies in optimizing materials to balance strength, aesthetics, and adaptability for enhanced patient satisfaction.[33]

Denture processing has evolved significantly over the years, improving efficiency, accuracy, and durability. Conventional denture processing involves the compression molding technique, where polymethyl methacrylate (PMMA) is mixed, packed into molds, and heat-cured. While this method remains widely used, it requires multiple manual steps, leading to possible errors in fit and polymerization shrinkage. Conventional processing is cost-effective and widely accessible, but it can be time-consuming and prone to dimensional inaccuracies due to thermal expansion and contraction.[34]

Injection molding has emerged as an improved method for denture fabrication, addressing some drawbacks of conventional processing. In this technique, fluid PMMA is injected into a mold under controlled pressure, ensuring better material distribution and reducing shrinkage. Injection molding produces dentures with enhanced density and fewer internal voids, leading to better mechanical

properties and increased durability. However, higher equipment costs and technical complexity make it less commonly adopted in smaller dental labs.

Recent advancements, such as 3D printing, have revolutionized denture fabrication by enabling digital workflows. Digital denture design allows precise customization, reducing errors associated with manual processing. Resin-based 3D printing facilitates the production of dentures with intricate details and minimal material waste. Additionally, rapid fabrication and improved repeatability make 3D printing a promising alternative. Despite these benefits, challenges such as material limitations, post-processing requirements, and potential brittleness of printed dentures remain concerns. [35]

While milling techniques also offer digital precision by carving dentures from pre-polymerized resin blocks, 3D printing is gaining more popularity due to its ability to fabricate intricate designs with less material waste. Ultimately, each processing method has its strengths and limitations, and the choice depends on factors such as cost, equipment availability, and specific patient needs.

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The impact strength of the complete dentures was evaluated using the Izod impact tester, in which a hammer strikes the specimen, and the impact resistance is recorded at the point of fracture. This method provides a quantitative assessment of the denture material's ability to withstand applied forces, helping determine its durability under functional conditions.

To assess the dimensional accuracy, STL files of the dentures fabricated using injection molding and 3D printing were superimposed using the best-fit alignment function. This technique allowed for a precise comparison of the denture surfaces, focusing on deviations across critical regions such as the residual ridge, palate, and denture borders. The conventionally processed dentures were used as the standard reference for accuracy assessment, enabling

a comparative evaluation of processing techniques and their effect on overall prosthesis precision.

The findings of this study demonstrated that 3D-printed dentures exhibited the highest impact strength, followed by injection-molded dentures, with conventionally processed dentures showing the lowest impact resistance. This suggests that 3D printing enhances material durability, making dentures more resistant to fracture under applied forces.[38]

In terms of dimensional accuracy, the results indicated that 3D-printed dentures again ranked the highest, ensuring superior fit and adaptation. Conventionally processed dentures followed in accuracy, with injection- molded dentures displaying the most deviations. The comparative analysis highlights the potential of digital fabrication techniques in achieving both mechanical strength and precision, reinforcing the advantages of 3D printing as an advanced method in denture fabrication.

4. CONCLUSION

Denture fabrication has evolved significantly, transitioning from traditional materials like vulcanized rubber and metals to more advanced options like polymethyl methacrylate (PMMA) and high-impact resins. Conventional compression molding remains widely used due to its accessibility and cost- effectiveness, though it is prone to polymerization shrinkage and manual errors. Injection molding has improved upon this by ensuring better material distribution, reducing void formation, and enhancing mechanical properties. More recently, 3D printing has revolutionized denture fabrication, introducing digital precision, customization, and efficiency. While milling techniques offer additional digital accuracy, 3D printing has gained prominence due to its ability to produce intricate designs with minimal material waste.

The study compared dentures fabricated using conventional, injection molding, and 3D printing methods, analyzing their impact strength and dimensional accuracy. Results showed that 3D-printed dentures exhibited the highest impact strength, followed by injection-molded dentures, with conventionally processed dentures showing the lowest resistance to applied forces. Similarly, in terms of accuracy, 3D-printed dentures ranked the highest, followed by conventional dentures, while injection-molded dentures displayed the most deviations. These findings emphasize the potential of digital fabrication techniques in improving

prosthesis durability and precision, with 3D printing standing out as a promising approach for modern prosthodontics.

Advancements in high-impact PMMA and 3D-printed resins reflect the ongoing pursuit of stronger, more accurate, and efficient denture processing methods. While Lucitone denture materials remain a gold standard in traditional fabrication, 3D printing offers greater personalization and digital precision, paving the way for future innovations in prosthodontics. Balancing strength, aesthetics, and adaptability will be key in optimizing denture fabrication for enhanced patient satisfaction and long-term prosthesis success

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