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-Dental Technology Department-

Evaluation The Effect Of Cellulose Nano Fibers On The Properties Of 3D Printed Acrylic Denture

A Project Submitted to the College Council of the College of Health and Medical Technology as a Partial Fulfillment of the Requirements for the Degree of Bachelorism of Dental Technology Department

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ﴾

صدق الله العظيم

(سورة المجادلة: 11)

- الإهداء -

بسم الله الرحمن الرحيم والحمد لله رب العالمين والصلاة والسلام على اخر الانبياء والمرسلين

رسول الله محمد وعلى اله ومن تبعهم بإحسان الى يوم الدين اجمعين

اما بعد: فاني احمد الله جل وعلا على ما اتاني من فضله, فقد هيأ لي كل الظروف ويسر لي انجاز هذا العمل بفضله العظيم

وكرمه العميم , فالحمد لله اقصى مبلغ الحمد والشكر من قبل ومن بعد

اهدي هذا البحث الى اصحاب الفضل الأول .. الشهداء جميعا لولاكم لما كنا هنا

الى من ساندوا خطاي المتعثرة الى رمزي المحبة والعطاء: امي وابي

الى رفقاء دربي منذ الصغر, وبهجة قلبي ,الى من تتبعوني خطوة بخطوة

الى سندي في الشدائد وملجأ روحي اخوتي واخواتي

الى من تحلو الحياة بهم ,الذين خففوا مشقة الطريق شركاء الحلم الكبير ,الى من كان وجودهم مصدر الحب والامل اصدقائي

هذا العمل حصيلة سهر ومحاولات وجهد ,يحمل بين سطوره اثر كل من كان سببا في الاستمرار

حتى هذه المرحلة

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ABSTRACT :-

Background several attempts: have been made for improving the properties of acrylic resin by adding some Cellulose Nano Fibers that have antifungal effect at the same time.

Aim of study. The objective of this study is to evaluate the effect of Cellulose Nano Fibers on hardness and roughness of 3D printed resin material.

Materials and Methods:- Total number 30 samples have been intended according to ADA specifications dimensions (65x10x2.5)mm length, width and thickness respectively were prepared by 3D printed acrylic resin, 10 samples prepared without additive Control. and 20 samples prepared with incorporation of Cellulose Nano Fibers in different concentrations (0.5%,1%), Hardness test was done by Shore D Burometer and roughness test by TR200.

Result: The hardness results showed slight variations among the groups. The 1% group presented slightly higher mean hardness values compared to the control and 0.5% groups, while the 0.5%group showed values close to the control however, the differences were not statistically significant ($P > 0.05$).In contrast, surface roughness values increased with the addition of the filler. The 1% group exhibited the highest mean roughness value, followed by the 0.5 %group, while the control group showed the lowest value, with a statistically significant difference among the groups ($P < 0.05$).

Conclusion :The addition of filler influenced the surface roughness of the material, while it had no significant effect on hardness. The 1% concentration produced the highest surface roughness values, followed by the 0.5% group, while the control group showed the lowest roughness values.

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CHAPTER ONE

Introduction

Chapter One

Introduction

1.1 Introduction:

In dentistry, non-metallic materials for denture manufacturing have a long tradition **(Duraccio, Mussano and Faga, 2015).** Among the first materials used, wood, ivory and dentin from hippopotamus teeth or even human teeth may be found. These types of dentures were considered a luxury, due to their prohibitive price and only rich people could afford them. Charles Goodyear discovered vulcanized rubber in 1839.

This was the premise for manufacturing dentures with rubber base, much cheaper and more accessible to any pocket. Celluloid, which appeared in 1871, was the first artificial polymer competing with rubber. But this was not able to overcome the drawbacks such as dimensional instability, deformability and problems in processing technology.

Resins represented a huge step forward in dentistry and the first heat-cured acrylic was reported in 1936 . First chemical studies regarding diacrylic composite resins- type urethane polymers were also carried out at that time by Otto Bayer in the IG Farben Laboratories in Leverkusen. Acrylics, in fact poly (methyl methacrylate) (PMMA) mixed with methyl methacrylate, dominated denture technology for several decades.

Poly (methyl methacrylate) (PMMA) has conventionally been the most common and the is oldest material used for fabricating complete dentures, owing to its advantages, such as excellent dimensional stability in oral environments, low cost, light weight, acceptable aesthetics, and the ease of fabrication and repair It has excellent transparency and aesthetics, which blend into the oral cavity without discomfort. However, there are many concerns related to the use of PMMA, including denture fracture caused by water sorption and impact, as well as the decrease in flexural strength, porosity, and

polymerization shrinkage Furthermore, the PMMA used in dental materials contains pigments that imitate oral tissue and additives such as nylon or acrylic synthetic fibers in a transparent powder component; the liquid component contains a cross-linking agent and an inhibitor, in addition to the main component, i.e., the methyl methacrylate (MMA) monomer. The non-uniformity of both components when mixing can lead to a decrease in material strength and bacterial invasion, which can decrease biocompatibility.

In recent years, computer-aided design and computer-aided manufacturing (CAD/CAM) technology has been applied to complete denture treatments. This has helped advance the digitization of denture production, because CAD/CAM technology enables production at a higher speed and accuracy, as well as at a lower cost compared to the manual production of dentures .

However, the surface properties of 3D printed materials have been shown to be problematic in general medicine and dentistry due to potential microbial adhesion to the material surface and in addition to it s surface roughens because of layer by layer nature of printing process.As a means to reduce or eliminate the creation of a biofilm on the denture surface, impregnating medical devices with plant -drived fibers has been suggested .

1.2 Aim Of Study:

The aim of this study was to investigate the mechanical and physical properties of three-dimensional (3D) printed denture base resin incorporating with Cellulose Nano Fibers.

CHAPTER TWO

Literature Review

Chapter Two

Literature Review

2.1 3D Printing:

3D printing is generally used to describe a manufacturing approach that builds objects one layer at a time, adding multiple layers to form an object. This process is more correctly described as additive manufacturing, and is also referred to as rapid prototyping (Andonović & Vrtanoski, 2010, Liu et al., 2006).

3D printing technologies are not all new; many modalities in use today were first developed and used in the late 1980s and 1990s (Strub J R et al., 2006) the author first treated a patient with the help of 3D printing in 1999.

The term '3D printing', however, is relatively new, and has captured the public imagination. A great deal of hype surrounds the use of 3D printing which is hailed as a disruptive technology that will forever transform manufacturing.

While we are very many years away from seeing the production of viable 3D printed organs, dentistry and oral and maxillofacial surgery have used 3D printing for years, and have whole-heartedly embraced the use of digital manufacturing technologies, notably, the use of computeraided design and manufacturing.

This article sets out to explore why 3D printing is important to dentistry, and why dentistry motivates development in 3D printing applications.

2.1.1 3D printing technology:

From a mechanical perspective, 3D printers are often quite simple robotic devices. The apparatus would be nothing without the computer-aided design (CAD) software that allows objects, and indeed whole assemblies to be designed in a virtual environment.

CAD software is commonplace in industrial design, engineering, and manufacturing environments, and is also common in the dental laboratory; it is even becoming a feature of many dental surgeries Developments in computer technology and software applications are very much a part of the groundswell of technological change that has taken 3D printing to where it is today.

For 3D printing to have value we need to be able to create objects to print; CAD software allows us to create objects from scratch, **(van Noort, 2012,Miyazaki & Hotta, 2011)** but in dentistry and surgery we also have ready access to volumetric data in the form of computed tomography (CT) data, cone beam computed tomography (CBCT) data, and intraoral or laboratory optical surface scan data.

Recent developments in CBCT and optical scan technology, in particular, have revolutionised, and are profoundly changing many aspects of restorative and implant dentistry. These powerful technological tools are at the disposal of a class of individuals – dentists and dental technicians – who are often polymaths, having a broad level of creativity and an understanding of technology, including engineering and materials skills that extend well beyond that of many others working in individual fields of endeavour.

Dentistry has a long association with subtractive manufacturing **(Azari & Nikzad, 2009)** – more usually described as 'milling'. Subtractive manufacturing is the removal of material to form an object.

CAD CAM for the milling of crown copings and bridge frameworks is now synonymous with modern dental technology. **(Miyazaki & Hotta, 2011)** Modern dentistry has a familiarity with materials designed to work with CAD CAM and to substitute for the more traditional precious metal casting alloys, **(Bammani S S et al., 2013)** which have been subject to exponential price increases in recent years.

This use of technology facilitates the use of materials, which would otherwise be hard to work with, and eliminates labour intensive artisanal production techniques,**(Venkatesh & Nandini, 2013)** allowing the dental technician to focus his manual skills on more creative aspects of the manufacturing process, for example the aesthetic layering of porcelain.Of course every time that a dentist operates to provide a restoration or reconstruction, the procedure is unique to that patient, that jaw, that tooth, or that implant.

The reconstruction or restoration will also have innate complexity requiring the reproduction of convoluted geometry with a high level of precision.(Witkowski et al. 2006) Although multiaxis CAD CAM milling processes will allow this to an extent **(Petzold et al., 1999)** the process is slow and wasteful as the material is milled from an intact block, and accuracy is limited by the complexity of the object, the size of the tooling, and the properties of the material.

3D printing, however, comes into its own for the accurate one-off fabrication of complex structures in a variety of materials with properties that are highly desirable in dentistry and in surgery. **(Sykes et al. 2004)**.

2.1.2 Applications of 3D printing in dentistry:

One of the earliest applications of 3D printing in surgery, medical modelling, may be thought of as the production of an anatomical 'study model **(Kurenov et al., 2015)** This has been made all the more accessible by another important technology that has become mainstream in dentistry in recent years; CBCT has become widely available in dental practices **(Adibi et al., 2012 ,Scarfe et al., 2006)** and has transformed diagnosis and treatment in implant dentistry and in endodontics. Ready access to CT, which provides similar data and is more prevalent in a hospital setting, or CBCT means that it is possible to provide volumetric 'image' data to a 3D printer before surgery and to make detailed replicas of the patient's jaws.

This allows anatomy, particularly complex, unusual, or unfamiliar anatomy, to be carefully reviewed and a surgical approach planned or practised before surgery **(Sinn et al., 2006)** This has led to the development of new procedures and approaches to surgery and along with the production of drilling or cutting guides using 3D printed technology or conventional laboratory technology, can lead to expedited, less invasive, and more predictable surgery **(Tardieu et al., 2007)** .

2.1.3 Advantages Of 3D Printing:

1. Speed

The main perk of 3D printing is primarily the speed at the rate of which the parts are generally produced in comparison to the traditional manufacturing approaches. The CAD model allows intricate designs to be uploaded and printed in a handful of hours. 3D printing also allows for rapid verification as well as the development of design concepts. **(Rangaiah, 2021)**.

2. Cost

In case of small production, 3D printing is a highly efficient and useful manufacturing process. Conventional prototyping approaches such as CNC machining necessitate a high number of costly machines and have higher labor expenses since they call for well experienced machine operators and technicians for operating them. **(Rangaiah, 2021)**.

3. Flexiblity

Yet another useful perk of 3D printing is that the given printer can develop anything fitting inside its build volume.

Through traditional manufacturing procedures, every fresh part or alteration in part design would need a fresh tool, mold or jig for being manufactured to develop a fresh part.

3D printing, as opposed to traditional approaches, permits the inclusion of multiple materials in a single object, allowing a range of colors, textures, and mechanical characteristics to be varied and coordinated. **(Rangaiah, 2021)**.

4. Competitive Advantage

Owing to the speed and lower expenses of 3D printing, the life cycles of products are minimised. Businesses can boost products, in turn enabling them to offer better items in a lesser time period. **(Rangaiah, 2021)**.

5. Tangible Design And Product Testing

The experience of feeling and touching the prototype of a product cannot be compared with looking at the product on the screen. The physical prototype can be tested and if any flaws are discovered the computer aided design file can be adjusted and a fresh version can be printed by the following day. **(Rangaiah, 2021)**.

2.1.4 <u>Disadvantages of 3D printing:</u>

1. Lesser Strength In Comparison To Conventional Manufacture

Many 3D printed parts are quite fragile as opposed to the conventional manufacturing approaches, apart from the ones created from metal which have effective mechanical characteristics. This is largely owing to the parts being constructed layer-by-layer, which highly minimizes its strength. **(Rangaiah, 2021)**.

2. Elevated cost at high volume

Generally carrying out large production operations is more costly through 3D printing owing to less impact from economies of scale. As per estimates, when a direct comparison is made between similar parts, 3D printing is deduced to be less cost-effective in comparison with the parts being developed using conventional manufacturing approaches. **(Rangaiah, 2021)**.

3. Limitations In Accuracy

The precision of a printed part relies on the kind of machine and/or procedure adopted. A few desktop printers have lesser tolerances in comparison to other printers, implying that the final parts can be different in comparison to the designs. Although this can be mended through postprocessing, it has to be ensured that 3D printed parts might not be precise every time. **(Rangaiah, 2021)**.

4. Post-Processing Requirements

Most of the 3D printed parts need a certain kind of postprocessing. This can be smoothing for developing a required finish or getting heat treatment for achieving particular material properties as well as final machining. **(Rangaiah, 2021)**.

2.1.5 Benefits Of 3D Printing:

1. Customization and Personalization

The greatest advantage that 3D printers provide in medical applications is the freedom to produce custom-made medical products and equipment. (Banks, 2013).For example, the use of 3D printing to customize prosthetics and implants can provide great value for both patients and physicians. **(Banks, 2013).**

In addition, 3D printing can produce made-toorder jigs and fixtures for use in operating rooms **(Mertz, 2013)** .Custom-made implants, fixtures, and surgical tools can have a positive impact in terms of the time required for surgery, patient recovery time, and the success of the surgery or implant.It is also anticipated that 3D printing technologies will eventually allow drug dosage forms, release profiles, and dispensing to be customized for each patient. **(Ursan, 2013)**.

2. Increased Cost Efficiency

Another important benefit offered by 3D printing is the ability to produce items cheaply. **(Schubert et al., 2014)** Traditional manufacturing methods remain less expensive for largescale production; however, the cost of 3D printing is becoming more and more competitive for small production runs. This is especially true for small-sized standard implants or prosthetics, such as those used for spinal, dental, or craniofacial disorders. **(Banks, 2013)** The cost to custom-print a 3D object is minimal, with the first item being as inexpensive as the last. **(Schubert et al., 2014)** This is especially advantageous for companies that have low production volumes or that produce parts or products that are highly complex or require frequent modifications. **(Mertz, 2013)**.

3D printing can also reduce manufacturing costs by decreasing the use of unnecessary resources. For example, a pharmaceutical tablet weighing 10 mg could potentially be custom-fabricated on demand as a 1-mg tablet. Some drugs may also be printed in dosage forms that are easier and more cost-effective to deliver to patients. **(Ursan, 2013)**.

3. Enhanced Productivity

"Fast" in 3D printing means that a product can be made within several hours. (Mertz, 2013) That makes 3D printing technology much faster than traditional methods of making items such as prosthetics and implants, which require milling, forging, and a long delivery time.In addition to speed, other qualities, such as the resolution, accuracy, reliability, and repeatability of 3D printing technologies, are also improving. **(Banks, 2013)**.

4. Democratization and Collaboration

Another beneficial feature offered by 3D printing is the democratization of the design and manufacturing of goods. An increasing array of materials is becoming available for use in 3D printing, and they are decreasing in cost. This allows more people, including those in medical fields, to use little more than a 3D printer and their imaginations to design and produce novel products for personal or commercial use. (**Mertz, 2013)**.

2.1.6 Uses of 3D Printer

3D printing is used in dentistry to obtain accurate images and models of the anatomy of a patient's teeth and jaws. An intraoral scanner captures the exact anatomy of a patient's mouth. The data from the scan is then used to construct a 3D-CAD model of the desired anatomy. The CAD file, once completed, is uploaded to a 3D printer and built. Dentists can go through several iterations before they obtain a model that is both accurate and comfortable enough for the patient. Using an intraoral scanner and corresponding images, dentists can also print surgical guides that help during an operation. This enables safer surgery, faster healing, and added prosthetic comfort. **(Xometry, 2023)**.

2.2 History of Resins in Dentistry

The period of 175 years from 1800 to 1975 represents one of significant advancement in prosthetic and restorative dental service. The transition from the time of ill-fitting dentures, fashioned from naturally occurring materials, to the application of synthetic resins for a long list of dental and surgical purposes described in this symposium, represents a typical example of technical and professional advancement that has taken place throughout the world society during this same period.

As noted in the beginning of this report, the advancement in dentistry has been possible through the cooperative efforts of contemporary scientists in many related fields. If dentistry retains this good working relationship, as it is expected to do, then the advancements within the next two generations can significantly change and improve the practice of dentistry from what is presently known, by the application of additional new and modified dental resins. **(Bowen, 2022)**.

2.2.1 Types Of Resin

Typically resins are divided into thermosets and thermoplastics based on whether or not the hardening reaction can be reversed. Widely used thermoplastic resins include ABS, polyethylene, polystyrene, and polycarbonate. Most common thermoset resins are polyester, vinyl ester, epoxy, and polyurethane.

Thermoplastic resins are basically the ones that can be melted and then hardened once cooled. Within the molecule chain of such resins, there are extremely strong bonds between molecules. Thermosets, on the contrary, undergo a non-reversible reaction resulting in a hard end product. It is determined by the process called polymerization or cross-linking which takes place in such materials caused by the use of a catalyst, heat or a combination of the two. **(Treatstock, 2023)**.

2.2.2 Resin Produced

Production of artificial resins starts from a so-called cracking process, which means that different types of hydrocarbons are heated up to separate molecules. Then polymer compounds are built in order to create a specific resin. **(Treatstock, 2023)**.

2.2.3 Resin Uses

Resins have numerous applications starting from jewelry making to manufacturing parts for sports cars. Different resins can be used by themselves as a base or as a gluing agent for materials like carbon fiber, fiberglass and more. **(Treatstock, 2023)**.

2.2.4 Advantages

- Precision.
- Large variety of resins with different properties.
- A wide range of applications.
- Can be food-safe.
- Can be easily colored, dyed, mixed with metal powders or fluorescent pigments.
- Easy to work with.
- Hardened resins can be machined **(Treatstock, 2023)** .

2.2.5 Disadvantages

- Some resins are toxic.
- Fast polymerization reaction requires being quick.
- Requires special storing (some resins are sensitive to moisture, temperature and light).
- Casting Resins need components accuracy.
- Low volume casting may require much handwork, which makes its net cost hig **(Treatstock, 2023)** .

2.3 Cellulose Nano Fibers

- CNF, or cellulose nanofibers, is defined as natural nanoscale fibers made purely from cellulose molecules, typically extracted from various cellulosic sources through mechanical and chemical treatments. These fibers exhibit high aspect ratios and can form web-like structures, making them attractive reinforcing materials for polymers and composites **(George et al., 2017)**.

2.3.1 Benefits of Cellulose Nano Fibers

1.High Strength

Cellulose nanofibers exhibit exceptional tensile strength **(Lee,2014)**.

2. Biodegradability

Cellulose nanofibers are fully biodegradable,reducing environmental impact **(Lee,2014)**.

3. Lightweight

They offer significant mechanical support without adding weight **(Lee,2014)**.

5. Versatility

Can be used in a wide range of applications due to their adaptable properties **(Lee,2014)**.

6.Enhances Barrier Properties

They improve moisture and gas barrier properties in materials **(Lee,2014)**.

2.3.2 Cellulose Nano Fibers Side Effects

Cellulose derived from natural sources is typically biologically inert; however, it can cause inflammation, fibrosis, and granuloma formation in the lungs when administered intratracheally to rats. This finding highlights the potential risks associated with the inhalation of cellulose-based materials, including CNFs **((Tátrai 1995; Kargarzadeh 2017)**.

2.3.3 Medicinal Uses

Cellulose Nanofibers (CNFs) are widely utilized in medicine as advanced wound dressings for moisture management and infection control, smart drug delivery systems for targeted

release, and biocompatible scaffolds for bone and tissue regeneration. They are also essential in rapid hemostasis to stop bleeding and in developing high-sensitivity diagnostic biosensors **(Kargarzadeh 2017; George 2017)**.

2.3.4 Incorporation Of Cellulos Nano Fibers into resin material

There were little studies study the effect of incorporation of Cellulos Nano Fibers into resin material
one of studies aimed to find the best amount of cellulose nanofibers to add to heat-cured denture base material to enhance its mechanical characteristics. Cellulose nanofibers (CNF) were added to the polymethyl methacrylate (PMMA) denture base in several weight percentages (0%, 0.5%, 1%, 1.5, and 2%). A probe sonicator was used to mix the monomer with the cellulose nanofibers for around 5 minutes. Impact strength, transverse strength, and shore D surface hardness were the three groups that were classified afterward according to the trials conducted. Descriptive statistics, including means, standard deviations, and bar chart visualisations, were utilized to analyze the data.
The findings indicate that the mean values of impact strength and transverse strength measurements exhibited a significant increase in the 0.5% and 1% cellulose nanofiber reinforcement groups, as compared to the control group. However, no significant increase was observed in shore D hardness. Other percentages (1.5% and 2% by weight of CNF) either significantly or insignificantly decreased the mean value of the results. The findings suggest that the incorporation of cellulose nanofibers at concentrations of 0.5% and 1% improves the mechanical properties of a denture foundation.

CHAPTER THREE

Materials & Methods

Chapter Three

Materials And Methods

3.1 Materials and Equipment

3.1.1 Materials Used in this Study:

1. Cellulos Nano Fibers .
2. 3D printing Resin .
3. Gloves .
4. Ethanol .

Figure (3-1): Ultra resins

Figure (3-2): Cellulos Nano Fibers

3.1.2 Equipment used in this study are :

1. 3D printer .
2. Ultrasonic cleaner .
3. chitobox software.
4. polishing disk dental bur.
5. Hardness Tester (Shore D Burometer-China).
6. Roughness Tester (TR200-Germany).

3.2 Methods:

3.2.1 Specimens grouping:

Thirty specimens were divided into Three major groups consisting of :

1. Group (one) :Control group: this group comprised of 10 specimens of 3D printed acrylic with no surface treatment.
2. Group (two): this group comprised of 10 specimens of 3D printed acrylic with 0.5% Cellulose Nano fibers surface treatment.
3. Group (three): this group comprised of 10 specimens of 3D printed acrylic with 1% Cellulose Nanofibers surface treatment .

3.2.2 Preparation of test specimens

Fabrication of three-dimensional specimen blocks

The designing procedure was done using software chitobox, the (3D) design was created virtually. The design of specimens for surface Hardness and surface roughness had specific dimensions according to specification for that test and materials. The design of surface Hardness and surface roughness test was the same which was bar shaped specimen according to (ADA No.12, 1999) with dimensions of (65x10x2.5 mm) length, width and thickness respectively.

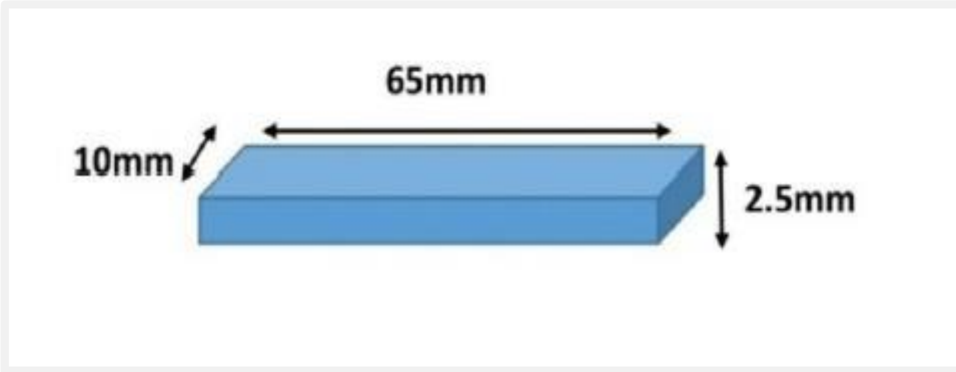

Figure (3-3): Surface hardness and Surface roughness specimen design.

3.2.3 Sample distribution

30 samples were constructed for this study , control group without adding fibers (0%), The experiment samples were divided for 2 groups according to Cellulose Nanofibers concentration (05%, 1%)each group (10) samples, these concentrations was add to resin as the following:

Table (3-1): Volume of Cellulose Nanofibers mixed with 3D printer resin

Cellulose Nanofibers concentrations	3D printed Resin	Cellulose Nanofibers (mg)
Control (0%)	100g	0g
Cellulose Nanofibers (0.5%)	99.5g	0.5g
Cellulose Nanofibers (1%)	99g	1g

3.2.4 Design by software

The samples were designed by using (chitobox) software before printing, to test the mechanical and physical property tests according to ADA specification with a rectangular bar 2.5× 10× 65 mm^3 . The sample plans were saved as STL file then imported into the 3D printing software .

3.2.5 Process of Printing

The file is exported to 3D printer software and printed with 90-degree angle. After completed the printing, the samples removed from the platform and cut the support structure from the samples then the samples was washed by (ethanol) 70% in an ultrasonic cleaner, to remove the excess monomer .

The samples were washed by two steps first prewashing 2 minutes and second post washing 2 minutes according to recommendation in ultrasonic and the left in air 30 minutes to dry before post curing.

Figure (3-4):Printing procedure while cover of printer closed

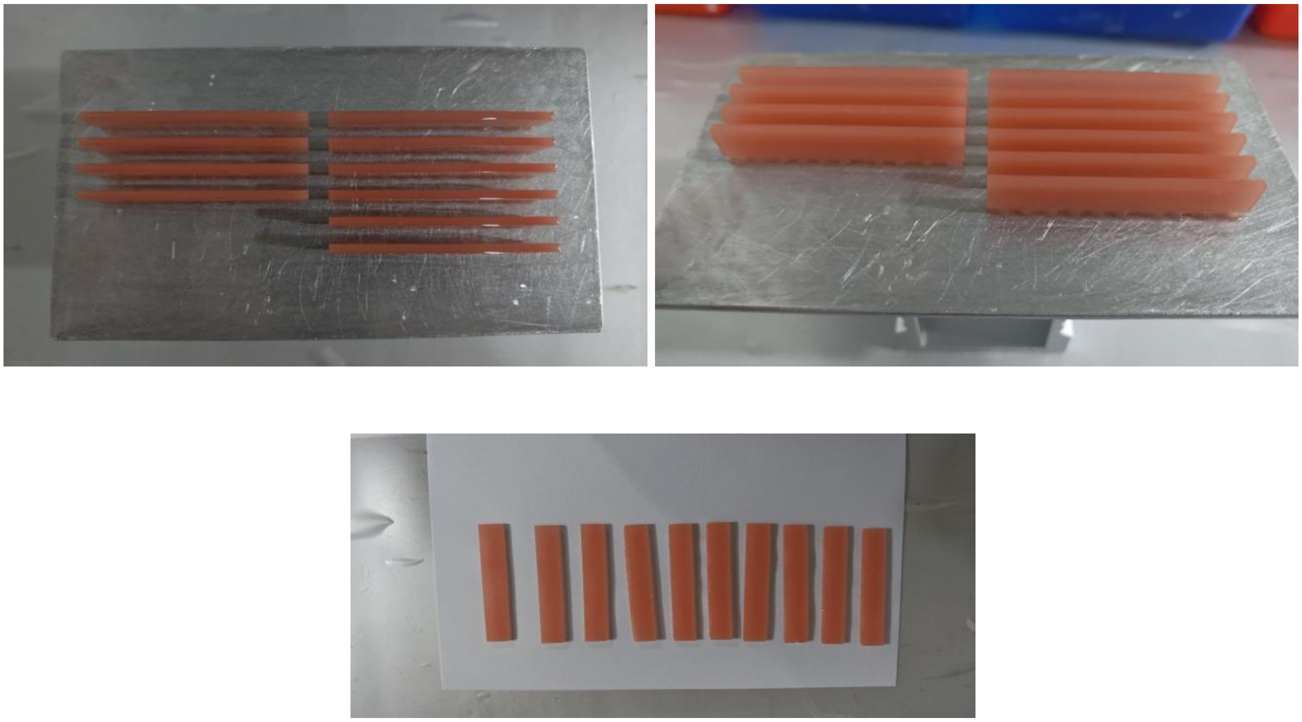

Figure (3-5) : Final printed specimens at the printer plate

Figure (3-6): Ultrasonic cleaner device

3.2.6 Post-curing procedure

Each group made from 3D printing resin after printing process, which subjected to post-curing that they were placed in the UV curing chamber for 10 minutes according manufacturer instruction of resin After completed post-curing stage, polishing disk dental burs are used to polish all specimens.

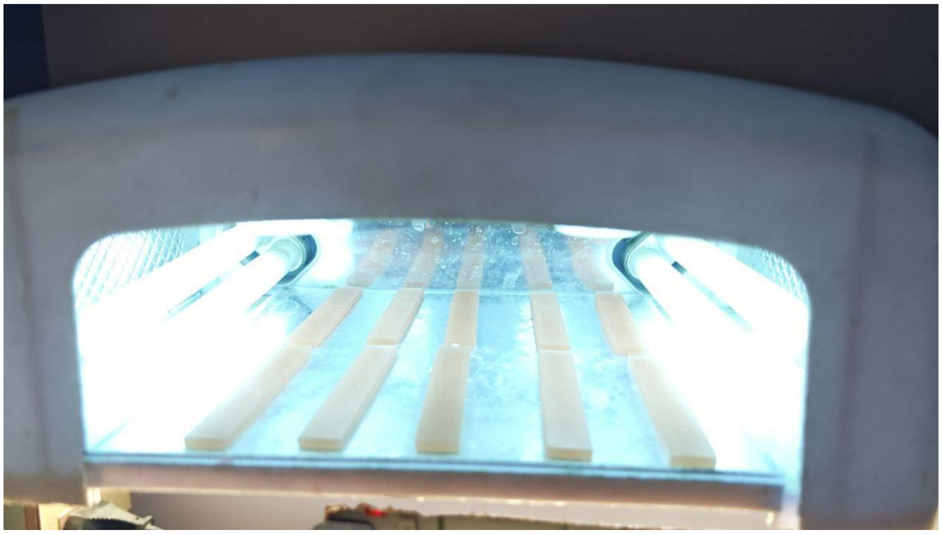

Figure (3-7): specimens made from 3D printing resin after printing process

Figure (3-8) : polishing disk dental burs

3.2.7 Surface Hardness test

In this study, a shore D hardness tester (Shore D Burometer , China) was employed to measure the hardness or indentation of the specimens. The shore D hardness apparatus was situated vertically above a flat specimen on a level, firm platform. The recording was obtained from the reading scale D di-rectly. The distance among the specimen surface and the hardness tester's indenter was (five) and (twelve) mm. The load was around (5 N). On each specimen, three spots with a (six mm) spacing between them were marked, and the hardness value was calculated by means of the average of these three readings with scale D. The reading was taking directly from the scale and calculated.

Figure (3-9): Hardness test by Shore burometr

3.2.8 Surface Roughness test

Bar shaped specimen printed with dimensions of (65x10x2.5 mm) length, width and thickness respectively (Eanooz, 2022), Surface roughness test was performed using surface roughness profilometer tester (TR200-Germany) with 0.001 micrometer accuracy at (Technology university), This tester contained a diamond sensitive needle (stylus) used to track the irregularities on the surface. Three separated locations on the specimen's surface were just touched by the stylus to have three readings for each sample, so according to profilometer instructions; the sample was located on a stable, rigid surface and the stylus should be allowed to contact the first point, then it was moved for 11 mm across the sample, the readings appeared on the digital scale in a spontaneous manner. Later, a roughness values were determined by calculating the mean values of these reading in μm.

Figure (3-10): Roughness test by TR200

3.2.9 Statistical analysis

The data were analyzed using Statistical Package for Social Sciences (SPSS IBM version 20.0) software . Descriptive statistics were presented as mean ± SD (standard deviation) and frequencies were expressed as percentages . One way ANOVA test was used and LSD test used to compare between two means . The level of significance (p - value) was set at ≤ 0.05 .

CHAPTER FOUR

The Results

Chapter Four

The Results

4.1 Descripitive statistics

4.1.1. Surface Hardness

Descriptive statistics are shown in Table (4-1), figure (4-1) for the surface hardness test which included (minimum, maximum value, mean, SD error, and SD) after addition of Cellulose nanofibers . The results revealed that the highest mean value of the hardness test was (81.160) after addition of 1% Cellulose while the lowest mean value of the hardness test was(80.570) after addition of 0.5% Cellulose nanofibers.

Table(4-1): Descriptive Statistics of the surface hardness test for process of addition of Cellulose nanofibers.

Groups	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Control	10	80.660	1.0967	.3468	78.3	82.3
0.5%Cellulose nanofibers	10	80.570	1.0853	.3432	79.0	82.0
1%Cellulose nanofibers	10	81.160	1.9962	.6313	79.7	85.0
Total	30	80.797	1.4301	.2611	78.3	85.0

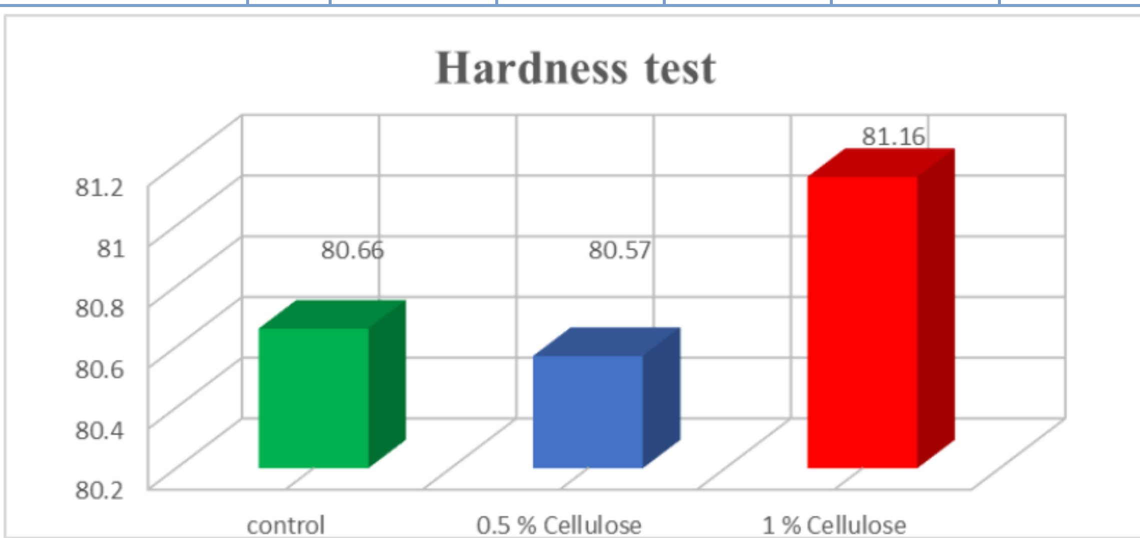

Figure (4-1): Mean distribution of surface hardness test for all groups.

4.1.2. Surface roughness

Descriptive statistics are shown in Table (4-2), figure (4-2) for the surface roughness test which included (minimum, maximum value, mean, SD error, and SD) after addition of Cellulose nanofibers The results revealed that the highest mean value of the roughness test was (1.48730) after addition of 1% Cellulose nanofibers while the lowest mean value of the roughness test was(1.32040) in control group

Table(4-2): Descriptive Statistics of the surface roughness test for process of addition of Cellulose nanofibers.

Groups	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Control	10	1.32040	.018081	.005718	1.299	1.341
0.5%Cellulose nanofibers	10	1.44570	.003164	.001001	1.441	1.451
1%Cellulose nanofibers	10	1.48730	.010531	.003330	1.462	1.496
Total	30	1.41780	.073105	.013347	1.299	1.496

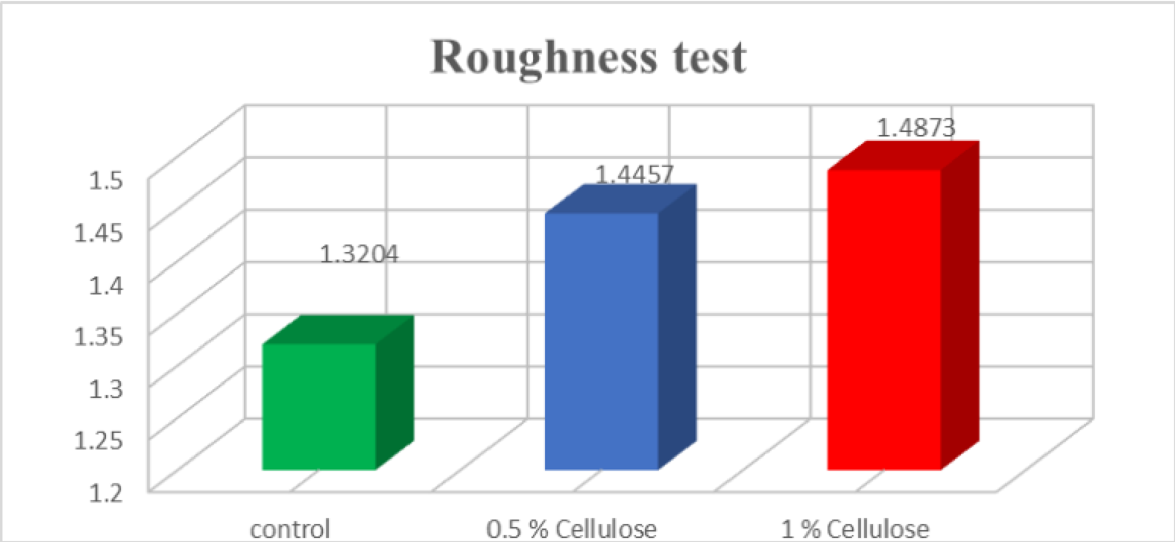

Figure (4-2): Mean distribution of surface roughness test for all groups.

4.2 Inferential Data Analysis

4.2.1. Surface hardness

A one-way ANOVA test was performed in order to indicate if there was a significant difference among groups. The results of this test revealed that there was no significant difference among groups value ($p > 0.05$)as shown in Table (4-3).

Table (4-3): One–way ANOVA to compare surface hardness.

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.021	2	1.010	.476	.626
Within Groups	57.289	27	2.122		
Total	59.310	29			

Multiple comparisons revealed that the significant different was between group 1 % group and 0.5% group as shown in table (4- 4).

Table (4-4): Multiple comparisons between groups by LSD test.
* The mean difference is significant at the 0.05 level

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	P-value	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
control	0.5 % Cellulose nanofibers	.0900	.6514	.891	NS	-1.247	1.427
	1 % Cellulose nanofibers	-.5000	.6514	.449	NS	-1.837	.837
0.5 % Cellulose nanofibers	1 % Cellulose nanofibers	-.5900	.6514	.373	NS	-1.927	.747

4.2.2. Surface roughness

A one-way ANOVA test was performed in order to indicate if there was a significant difference among groups. The results of this test revealed that there was highly significant difference among groups value (p > 0.05)as shown in Table (4-5).

Table (4-5): One–way ANOVA to compare surface roughness.

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	151	2	.075	505.603	.000
Within Groups	004	27	.000		
Total	155	29			

Multiple comparisons revealed that the significant different was between group 1 % group and control group was highly significant group as shown in table (4-6).

Table (4-6): Multiple comparisons between groups by LSD test.
* The mean difference is significant at the 0.05 level

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	P-value	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
control	0.5 % Cellulose nanofibers	-.125300	.005464	.000	HS	-.13651	-.11409
	1 % Cellulose nanofibers	-.166900	.005464	.000	HS	-.17811	-.15569
0.5 % Cellulose nanofibers	1 % Cellulose nanofibers	-.041600	.005464	.000	HS	-.05281	-.03039

CHAPTER FIVE

Discussion

Chapter Five

Discussion

3D printing plays a very important role in fields such as dentistry, medicine and medical devices. In recent years, three-dimensional (3D) printing has improved rapidly, in terms of reliability and accuracy, leading to its application in the medical field.

The aim of 3D printing is to produce rapid and functional materials. The 3D- printed object was built layer by layer while the build plate is adjusted to allow the next layer to cure. Multiple factors must be kept under control during the 3D- printing process.

The properties are influenced by the layer thickness, depth of polymerization, shrinkage, and intensity and direction of the light from the source.

Acrylic resin is the most frequently used material for denture bases. However some disadvantages like poor mechanical properties, attempts made to strengthen acrylic resin materials properties, by adding various reinforcing materials such as fibers, nanoparticles (Azumetal,1999 , Jordan et al., 2005).

Cellulose nanofibers are primarily used as a reinforcing material to improve the mechanical properties of acrylic resins (Polymethyl methacrylate - PMMA) used in denture bases and other prosthetic devices. Research indicates that their effect is highly dependent on the concentration added and the preparation method.

In the present study, the addition of cellulose nanofibers at different concentrations (0.5% and 1%) showed a noticeable effect on the hardness and surface roughness of the 3D- printed resin material. This improvement can be attributed to the reinforcing effect of the nanofibers which act as stress-bearing components within the polymer matrix, leading to better load distribution and resistance to deformation

Regarding surface roughness, the addition of cellulose nanofibers showed variable effects depending on the concentration used. At lower concentrations (0.5%), the nanofibers may be well-dispersed within the matrix, resulting in a relatively smooth surface. However, at higher concentrations (1%), agglomeration of nanofibers may occur, leading to an increase in surface irregularities and, consequently, higher roughness values

From a clinical perspective, increasing hardness was beneficial as it enhances the durability and wear resistance of denture base materials. However, increased surface roughness may promote plaque accumulation and microbial adhesion, which could negatively affect oral health. Therefore, a balance between improved mechanical properties and acceptable surface characteristics is essential.

Within the limitations of this study, it can be concluded that the addition of cellulose nanofibers has a positive effect on the hardness of 3D printed acrylic resin,while its effect on surface roughness depends on the concentration used.

CHAPTER SIX

Conclusions & Suggestions

Chapter Six

Conclusions & Suggestions

1. Conclusions

1. The addition of cellulose nanofibers (0.5% and 1%) to 3D-printed acrylic resin material showed no statistically significant effect on surface hardness .

2. The addition of cellulose nanofibers (0.5% and 1%) to 3D-printed acrylic resin material significantly increased surface roughness . The 1% group showed the highest roughness values, followed by the 0.5% group, while the control group exhibited the lowest values.

2. Suggestions

1. Assessment of the effect of Oyster powder on the hardness of the 3D printer acrylic resin denture base.

2. Challengesand comparative the effect of 3% & 5% of cellulose nanofibers on properties of 3D- printed acrylic resin material.

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