

DESIGN AND RE-MODELLING OF CUSTOMIZED TOOTH CAP USING 3D PRINTING

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Technology degree in Biomedical engineering

by

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Vukka lakshmidhar (38240042), Parthasarathy s (38240022)** who carried out the project entitled "**Design and re-modelling of customized tooth cap using 3D printing**" under our supervision from **September 2021 to March 2022**.

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We, **Vukka Lakshmidhar (38240042)** and **Parthasarathy S (38240022)** hereby declare that the Project Report entitled “**Design and re-modelling of customized tooth cap using 3D printing**” done by us under the guidance of **Dr. J. PREM KUMAR**, M.Sc., Ph.D. Department of Biomedical Engineering is submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Biomedical Engineering.

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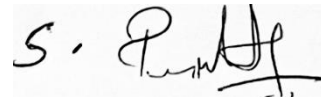
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ABSTRACT

This paper aims to show, based on factual information, to what extent 3D printing can be used in dental laboratories and dental practices at present. It attempts to present a rational evaluation of today`s applications of 3D printing technology in the context of dental restorations. In addition, the article discusses future perspectives and examines the ongoing viability of traditional dental laboratory services and manufacturing processes. It also shows which expertise is needed for the digital additive manufacturing of dental restorations and a case report of prosthetic treatment built upon 3D technologies for manufacturing of dental restorations.

Using of 3D printing may shows a drastic change in the field of dentistry. Our aim is to use Bio-ceramics and Co-polymer as a bio- compatible materials for tooth cap (Crown). CAD software is used to design and simulate the tooth cap in viable environment such that there is no miscible after the implementation. Bio-materials elicits no toxic, mutagenic, or inflammatory responses within the human body and it has low water absorption which tends to have minimal or no cracks to the compound and also shows no effect to the gums. These biomaterials also useful in preventing the tooth cap getting coloured or stained early.

Keywords: Tooth crown, 3D technology, Selective laser sintering, Bio-Ceramics.

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CHAPTER 1

1.1 GENERAL INTRODUCTION OF TEETH

1.1.1 *What is Dentistry?*

Dentistry governs on the oral health of an individual by diagnosing and treating the underlying problems and diseases of the oral cavity. It includes the teeth and it has surrounding structures called periodontium which is the cementum, periodontal ligament, gingiva and alveolar bone. Teeth are the rigid portion of human body. Humans will come across two sets of teeth in their lifespan.

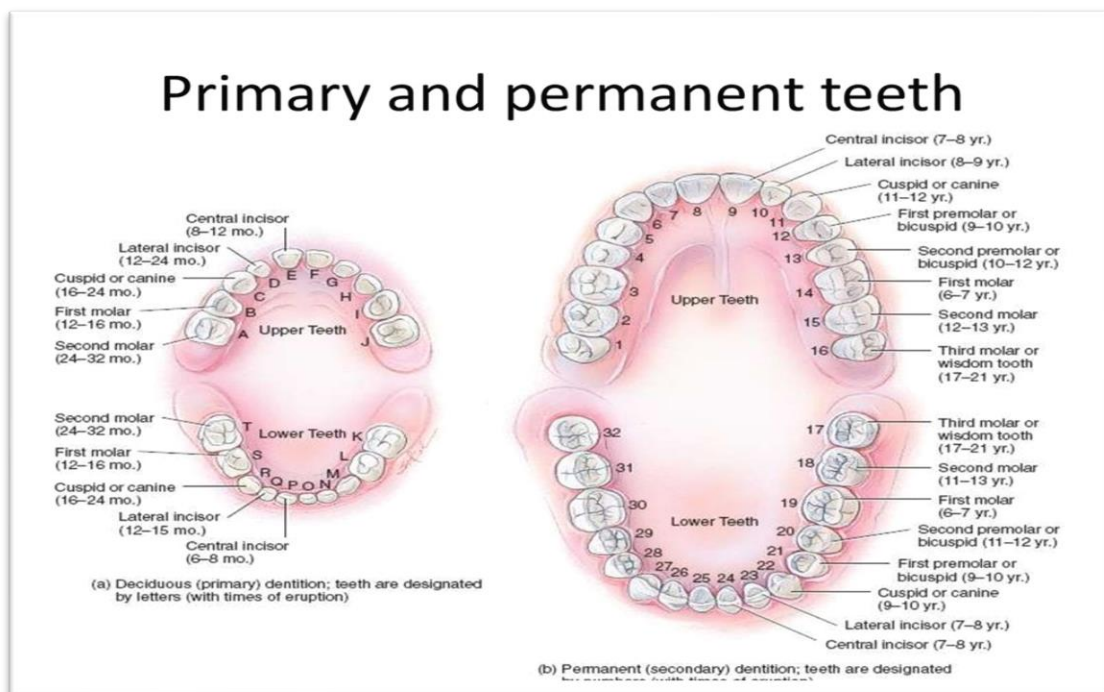


Fig 1.1 – Primary and permanent teeth

Primary or Deciduous teeth are the first set of teeth for humans. Primary teeth start to arise in oral cavity at age of 6 to 8 months. primary teeth remain till the age of 6 years and baring loss of teeth occurs due to bad oral health or trauma. The time of loss of primary teeth the permanent teeth start to grow

The jumble of two sets of teeth will last for 6 to 12 years of age. At discarding of all primary tooth the permanent teeth will start growing in oral cavity.

There are eight different specialties in dentistry, they are:

Oral and maxillofacial surgery:

It is the surgical specialty that deals with trauma in oral cavity and in head and neck region. It also includes cosmetic surgery and reconstructive surgery of face.

Endodontics:

It is the conservative part of dentistry which always focuses on maximum conservation of the tooth. Cavity preparation and root canal treatment are the main stream in this part of specialty.

Prosthodontics:

It is the aesthetic part of dentistry which concerns on both the appearance and complaint of an individual. Preparing of complete dentures and Removable partial dentures for edentulous and partly edentulous patients are major part of this specialty.

Orthodontics:

It is concerned with smile correction, where dental braces are reinforced for proper alignment and occlusion of teeth. Jaw correction and problems associated with TMJ are dealt with this specialty.

Pedodontics:

It is basically for children from 1 to 12 years old and deals with all the oral problems of children falling between that age group.

Oral medicine and radiology:

All diagnosis and treatment planning are done in this specialty. IOPAs taken here plays a vital role in the process of identification and progression of treatment.

Periodontics:

The major concern is the gum of the teeth and its surrounding structure and tissues. Diseases of periodontium and its treatment planning the main course of this specialty.

Public health industry:

It is more about creating awareness to the public regarding the evolved treatments, diseases and its prevention. They emphasize more on dental health and educate the public about the importance of dental health and hygiene.

Nomenclature of human teeth:

The teeth are the hardest structure present in human body. They are arranged in upper and lower jaws of the buccal cavity. The maxillary jaw is the upper jaw and the mandibular jaw is the lower jaw. The teeth present in the maxillary and mandibular part are called maxillary and mandibular teeth respectively.

There are two classes of human teeth, they are anterior and posterior. Anterior are the teeth which are found in anterior part of the mouth, they include central and lateral incisors and canines. Posteriors are the teeth that are found in the posterior part of the mouth and they include all the premolars and molars.

Humans have Diphyodont dentition. They have two sets of teeth, the primary or deciduous dentition which is replaced by secondary or permanent dentition. The primary dentition is encountered from 8 months to 6 years of age. They are 20 in number, 10 in maxilla and 10 in mandible. The teeth present are central and lateral incisors, canines and molars, in permanent dentition the molars are replaced by premolars and they are followed by molars and thereby giving 32 in number, 16 in maxillary and 16 in mandible.

For identifying the individual teeth in proper way there are certain systems which are followed and that has made the identification easier and simpler. The major three systems that are used in daily life practices are the universal system, Zsigmondy/Palmer system, FDI system. Systems are essential for the proper identification of tooth and for using them for further references. All the systems have its own pros and cons, despite of all the most accepted and universally used system is FDI system.

1.1.2 ANATOMY OF TEETH:

Tooth is a highly calcified structure. The tooth is harder than a bone and its rigidity plays a vital role in masticatory process. Presence of teeth in the oral cavity helps not only in chewing of food but also helps in phonation and speech.

They stand as a physical hard barrier of buccal cavity. Tooth is composed of enamel, dentin, pulp and the surrounding structures called cementum, periodontal ligament and alveolar bone.

1.1.2.1 Enamel:

It is formed by 96% of inorganic material and 4% of organic material and water. It is formed by ameloblasts. It is the hardest calcified structure and it is made up of enamel rods. The striations, incremental lines, Hunter Schreger bands, enamel lamellae, enamel tufts and enamel spindles are the other structures of enamel which can be seen in ground section.



Fig 1.2 – tooth anatomy

1.1.2.2 Dentin:

It is harder than a bone but softer when compared to that of the enamel. It prevents the fracture of the hard overlying enamel by its property of deform ability or elasticity.

Dentin is tubular in structure and has dentinal fluid in it. The exposure of dentin causes sensitivity. Reparative dentin helps in fixing the damaged part in case of less problems.

1.1.2.3 Pulp:

It is the vital structure of the tooth. Infection of pulp causes many diseases. the severity leads to loss of tooth. Pulp resembles the morphology of tooth. it has pulp horns and roots in respect to the cusps and root of the tooth.

1.1.2.4 Periodontal ligament:

It is made of fibres that helps the tooth to attach itself in the socket. The PDL has loose connective tissues, Oxytalan fibres, blast and clast cells and cell rest of Malassezia.

1.1.2.5 Cementum:

The major function of cementum is that it provides anchorage to the tooth along with the main fibres of periodontal ligament and alveolar bone. It lines the root part of the tooth and it is a calcified structure.

1.1.2.6 Alveolar bone:

It is the hard bony socket made of osteoblasts. It holds the teeth in maxillary and mandibular jaws.

1.1.3 ***Why dental crowns are used?***

When you get your teeth damaged. This happens because of many reasons like tooth decay, injuries or over use. Teeth can lose their original shape and size over time. Dental crowns or caps are used to get your teeth to original shape after they get changes. It restores strength and appearance too.

Crowns will protect your loose tooth from breaking and restoring it, covering & supporting the filled tooth, helping in avoiding coloration. These crowns are made up of different materials. They are:

1.1.3.1 *Gold crowns:*

These dental crowns are combination copper and other metals such as chromium and nickel. Gold crowns are very stronger than other crowns and they won't break down easily and gives a good life. They easily last for 20 to 40 years. They fittings are perfect and they won't shrink easily. Gold crowns are mainly used in crowns because the able



Fig 1.3 – Gold crown

to control the pressure of chewing. They are biocompatible, non-toxic, anti-corrosion and versatile gold crowns have some side effects for some people they cause swelling, lip and mouth pain, gum irritation, oral lichenoid reaction, redness and appearance. Gold crowns are available in market at cost of 2500 – 15000 INR.

1.1.3.2 Porcelain crowns:

Porcelain crowns are most popular crowns in market because they match to the colour of tooth. They are made up of feldspathic porcelain. They give the glassy appearance and they are ceramic family. Porcelain crowns are the best for front tooth restoration. They won't exhibit any allergic reactions too.



Fig 1.4 – Porcelain crown

Porcelain crowns are provided by a warranty of 5 to 15 years and cost will change with the number of teeth, shape and size of need and the cost of single crown is around 5,000 INR. Porcelain crowns are not strong as gold or metal crowns. They should be taken care more to give life. These are most costly crowns, fragile, the original teeth are grounded more into the gums and they cause more hot and cold sensitivity.

1.1.3.3 Porcelain fused to meta l(PFM):

Porcelain fused to metal crowns are made of porcelain and metal mixture crowns. They give both strength and natural look as tooth. They're less in price than porcelain crowns. Porcelain fused metal crowns repair the damaged teeth and they contain good mechanical properties. PFM crowns contain metal which exhibit a dark line at the surrounded gums of the crown, the natural teeth should be grounded more and they produce allergic reactions. PFM crowns are given by warranty of 5 to 15 years and each crown cost about 6,000 INR.



Fig 1.5 – PFM crown

1.1.3.4 Zirconia crown:

Zirconia crowns are new to market they produce both the metal properties and gives an appearance of porcelain in outlook. They are long in life and the production process in making in zirconia crowns are less when compared with other crowns and they have great strength and they're biocompatible and won't produce any allergic reactions.



Fig 1.6 – Zirconia crown

They are strength makes them to break down sooner and they are very solid in structure so they are difficult to adjust. The single zirconia crown cost around 10000 to 25000 INR. Zirconia crowns comes with lifespan of 10 years.

1.2 3D PRINTING TECHNOLOGY:

3D printing is also called as additive manufacturing process, it is building of bodily three-dimensional object using computer aided design (CAD) software. The 3D object is constructed layer by layer using a computer made design. With this process we can create difficult structures or materials in less span of time with best quality. In comparison to other methods, we don't need extra tools or equipment to construct the product. 3D printing is reverse process of subtractive manufacturing which is welding out a piece of metal or plastic.



Fig 1.7 – 3D printer

- **Modeling:** 3D models are designed by CAD software, via a plain digital camera or 3D scanner. The designs created by CAD get a few errors in it. These errors are recognized and corrected before printing a model. It is a process of collection of all the digital data on the structure and outlook of a real object and constructing a digital model based on it. CAD models are saved in STL. CAD file stores the data based on curved triangulations of models. But STL is not customized for large file sizes of parts and surfaces. So, later on AMF was introduced to store large curved triangulations.
- **Printing:** The 3D model should be tested for errors in prior of printing from STL file. CAD application most errors in – holes, face normal, intersections, manifold errors and noise shells. The “repair” step in the STL fix such errors in model. After getting repaired these file needs to go under software called a “slicer”. Which makes the 3D design in continue layers and gives a file contains instructions to a 3D printer. Printer resolution will finalize the layer thickness and XY resolution in μm . designing and making of model takes around several days and hours with contemporary ways but by using additive process, we can reduce the time.
- **Finishing:** The resolution produced by printer is sufficient for maximum applications, but by printing oversized of the desired object gives greater accuracy and we can remove the material using high resolution subtractive process. Multiple colors and combinations can be made in some additive techniques which doesn't require painting section separately. Some specified polymers allow the smoothed and improved surface finishing by using chemical vapor processes based on the solvents used. This is the post-processing of object which makes flatten. So, that the object looks perfect and professional.
- After each printing is complete machine need to pull off the print on the build plate using a hammer or scrapper and polls and rods should be cleaned with vacuum. For each print the filament needs to be removed.

1.2.1 TYPES OF 3D PRINTING:

The 3D printing have several technologies to manufacturing an object layer by layer. Each differs in the way they build the parts, materials they use, finishing, cost and durability.

Selecting the correct process for the application demand to know about the pros and cons of each process. It is good to say that 3D printing is mostly used for prototyping. It will manufacture the single part in quick time which makes the developers to validate and share their ideas.

The major difference between additive manufacturing and 3D printing is 3D printing specifically involves in creation of product by building up layers of object. But, in additive manufacturing it makes the object by adding the material, which will not make layers in creating an object.

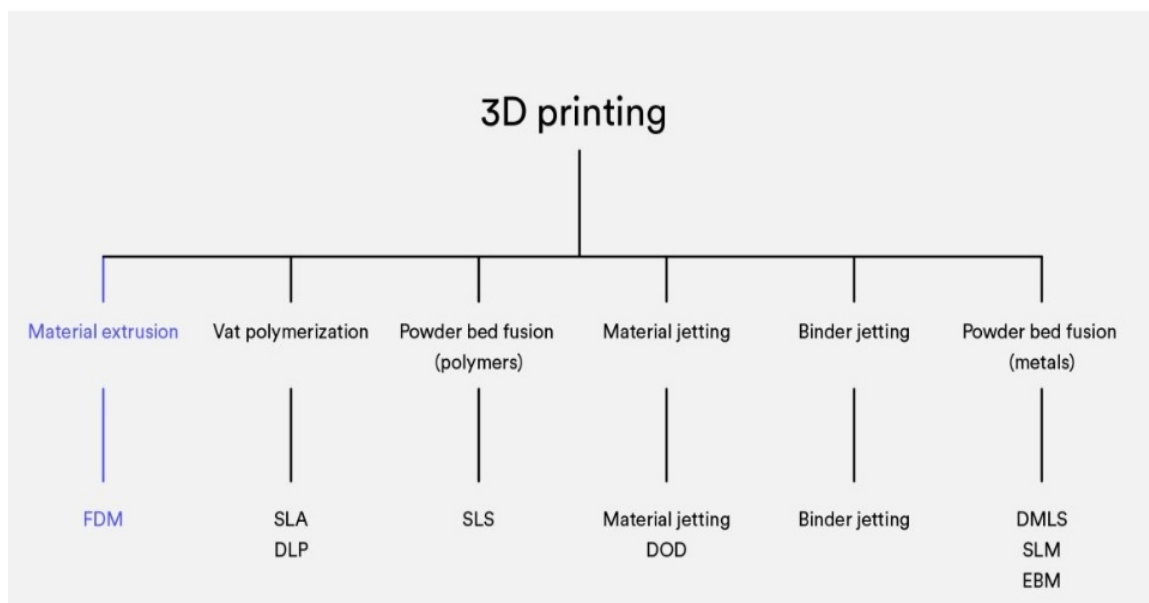


Fig 1.8 – Types of 3D printing

Five considerations for 3D printing:

- Geometry
- Cosmetic appearance
- Budget
- Mechanical requirements
- Material selection.

1.2.1.1 Fused deposition modeling (FDM):

Fused deposition modeling is also called as fused filament fabrication (FFF). It is an additive manufacturing process. In this process, the object is built in layer by layer. It is the first and most widely used technology. It is the process where that works both vertically and horizontally with the help of an extrusion nozzle on the build platform.

Working:

- At first, load a spool of thermoplastic material into the printer. The filament will pass to the extrusion head and start melting, once the nozzle reaches to desired temperature.
- The extrusion head allows it to move in three directions XYZ. Melted material is ejected out in slim strands and form layer by layer in notified locations, where it gets cool and become a solid. Fans are connected to extrusion head to make the cooling process fast.
- To fill the specific area and color it takes multiple passes to complete. When one layer is completed the build platform goes down and new layer is filled. This process is repeated until the object is completely made.
- In post-processing, after the completion of FDM printing, there are variety of post-processing methods for FDM like cold welding, polishing, priming etc.

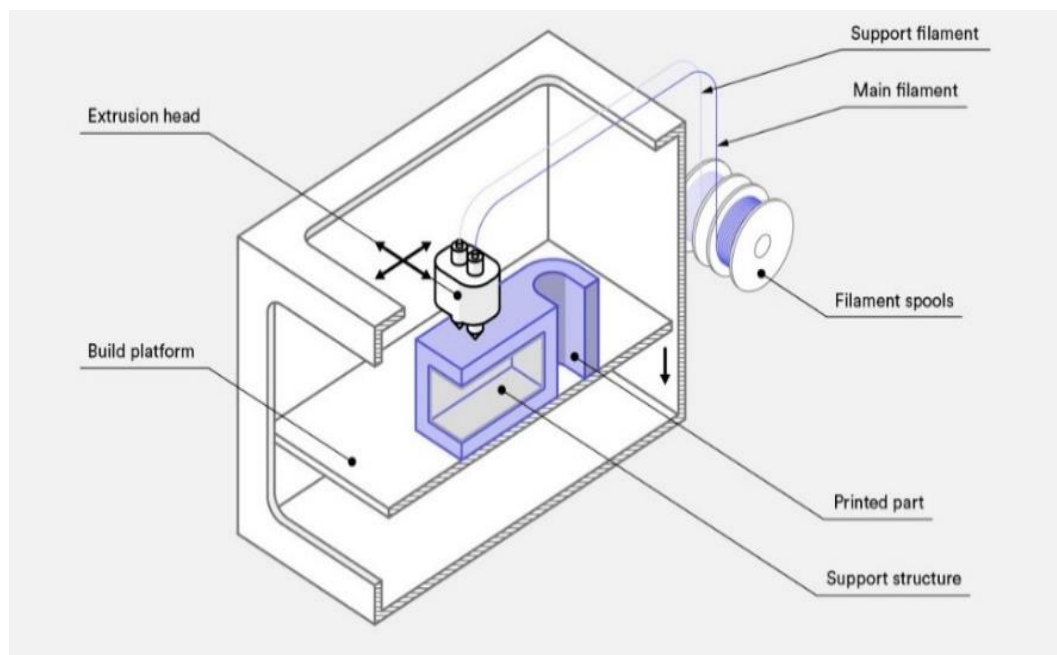


Fig 1.9 - FDM

Characteristics:

Table 1.1 – Characteristics of FDM

Materials	Thermoplastic (PLA, ABS, PEI, PC)
Dimensional accuracy	$\pm 0.5\%$ - desktop $\pm 0.15\%$ - industrial
Build size	200×200×200 mm – desktop 900×600×900 mm – industrial
Layer thickness	50 to 400 microns
Support	Not always required

Pros:

- Cost effective to make custom parts and prototyping.
- Broad range of materials are available.
- Coding is used to build object in high quality and accurate.
- Easily portable and less complex.

Cons:

- Low resolution.
- Longer printing time.
- Rough surface finishing.
- Weak in strength.

1.2.1.2 Stereolithography (SLA):

It is an additive manufacturing process, which is part of vat photopolymerization and also called as resin printing. This technology use light as source. To a polymer resin the UV lasers are used. The materials in SLA are photosensitive thermoset polymers in liquid form.

Working:

- At first, the build platform is placed in liquid photopolymer, at only layer height from the surface of liquid. Photopolymer resin is solidified and cured selectively in the next layer by UV lasers.
- At the photopolymerization process, the single carbon links that filled with liquid resin is generated by the light of UV lasers and become rigid part, making unbreakable strong bonds between them.
- The overall area of the model is scanned using galvos because the whole part is solid. After printing, the part is not fully in a cured state.
- It should go under post-processing under UV light.
- We can't convert the solid part to liquid resin because photopolymerization is irreversible process. Heating the part leads to burn instead of melting because they are thermoset polymers.

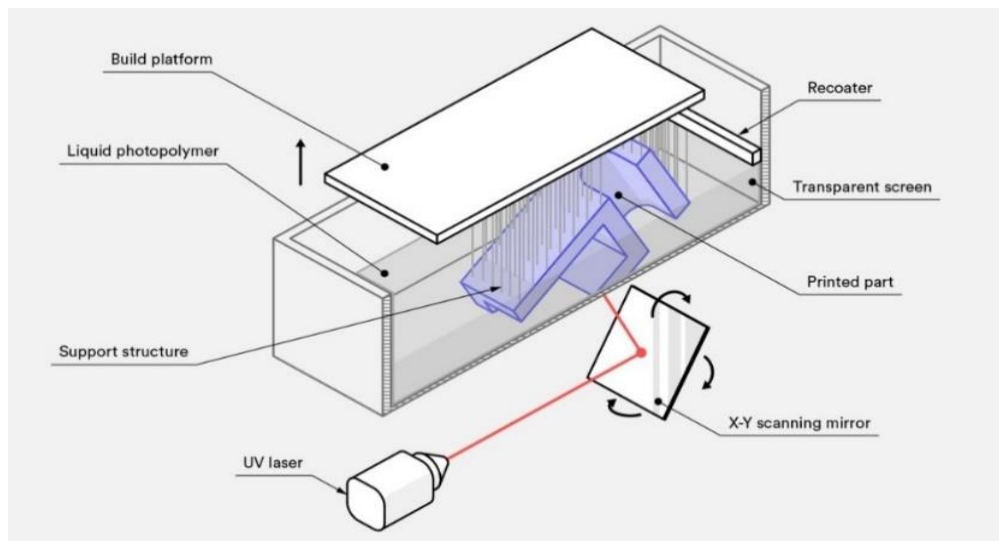


Fig 1.10 – SLA

Characteristics:

Table 1.2 – Characteristics of SLA

Materials	Photopolymer resins (thermosets)
Dimensional accuracy	$\pm 0.5\%$ - desktop $\pm 0.15\%$ - industrial

Build size	145×145×174 mm - desktop 1500×750×500 mm – industrial
Layer thickness	25 – 100 µm
Support	Always required

Parameters:

Parameters are manufacture fixed and they cannot be modified.

- Build size
- Top-down printers
- Bottom-up
- Layer height.

Pros:

- High dimensional accuracy parts.
- It has very soft and smooth finish.
- They are available, flexible and castable resins.
- Tight tolerance.

Cons:

- They brittle and not acceptable for functional prototypes.
- They will get degraded when they are exposed to sunlight due to mechanical properties.
- There will be a visual-marks on part and support structures are required.

1.2.1.3 Selective laser sintering (SLS):

Selective laser sintering is type of technique in 3D printing. It is an additive manufacturing (AM) technology which makes powder particles into solid substance by using a great laser source based on 3D outlook. This is low-cost, produce high quantity and they don't require support structures.

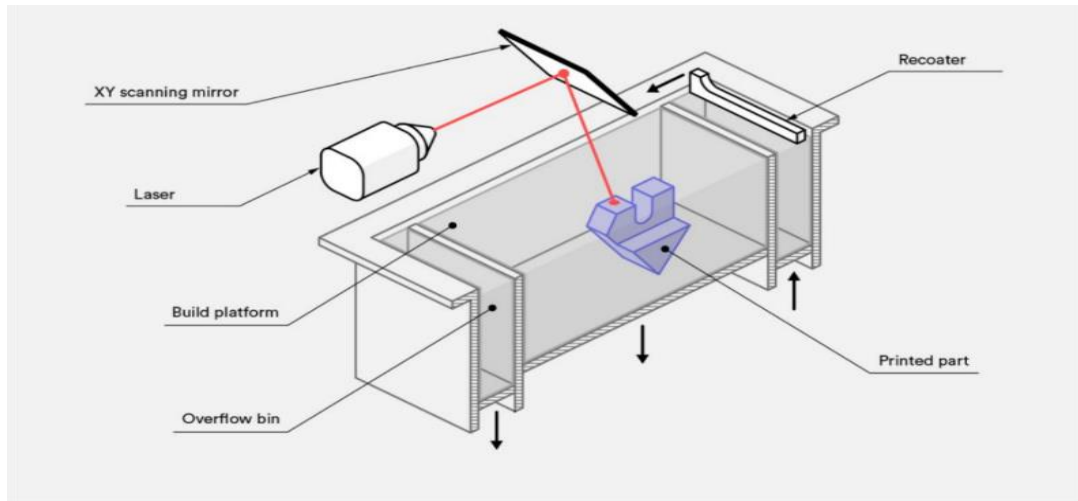
Characteristics:

Table 1.3 – Characteristics of SLS

Materials	Thermoplastics
Dimensional accuracy	$\pm 0.3\%$ (lower limit of 0.3 mm)
Build size	300×300×300 mm
Layer thickness	100 – 120 μm
Support	Not required

Working:

- In the top of a platform which is in the build chamber a powder is dispersed in a thin layer.
- The powder placed on the platform is preheated at temperature below the melting point of the raw material.
- The laser scans the dimensions of 3D model and start heating the powder to the melting point.
- This makes the raw material particles to fuse and create a solid part.
- The unfused powder supports during printing and deny the need for support structures.
- The platform goes down by itself from one layer to another to build a structure.
- this process repeats until the structure is complete.
- After the completion of printing, the build part should be cool down inside the print enclosure.
- The outside the printer should ensure that optimal properties and should avoid warping in structure.
- The finished parts required to be taken out from the build chamber, segregated and washed off the extra powder.
- The extra powder is recycled and the parts printed are further post processed by media tumbling.



Pros:

- Batch printing is easy and no need of support.
- Detailed in prints and high dimensional accuracy.
- Experimental use and cost of printing is low.

Cons:

- Raw material varieties are limited.
- Recycling cannot be done.
- Health hazards may occur.
- Brittle in nature and post-processing is difficult.

SLS takes powdered particles together and make it into solid form. Many SLS products are utilized for prototypes. The mainly used material for SLS is nylon.

1.2.1.4 Digital light processing (DLP):

DLP is a type of 3D printing technology, it is mostly used for photopolymer parts. It is very similar to SLA technology. The only difference is in DLP we use projected light source to cure the entire layer. It is used to print toys, dental molds and structures with fine design. But it is faster process than SLA.

Working:

- The tank is filled with liquid photopolymer and build platform is placed in it. The height between the tank and build platform is one layer.
- A light ray is passed through source. The next layer is created by curing and photopolymer resin is solidified. Ray of light has particular path in which it travels
- Now galvanometers monitor the path, which are placed on the particular path. Once the layer is solidified. It moves on to the next layer and the same process is repeated until the part is designed.
- The sweeper blade will recoat the surface constantly. Post-processing under the light rays is required for the products are high.

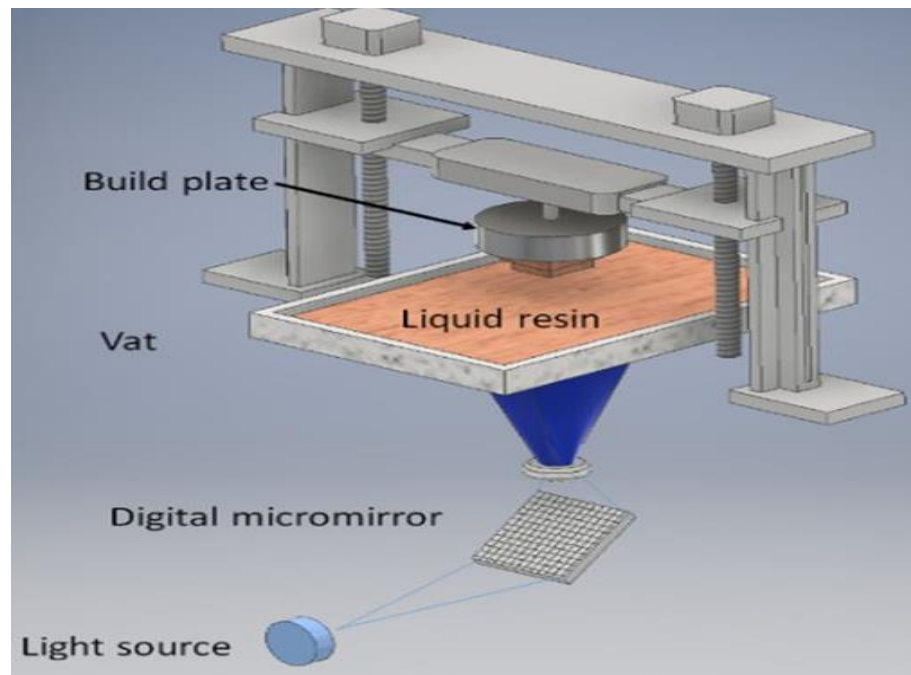


Fig 1.12 - DLP

Pros:

- High accuracy.
- High print speeds.
- fast production.
- Affordable prices.

Cons:

- Strong odors are produced because melting of photopolymers.
- Risk in warping.
- Small build volume.
- Low resolution.

DLP produce the smooth and soft surface finish whereas in SLA they won't. the main similarity is usage of resins in both. The manufacturer has to decide whether to use laser beam or light source. DLP are the best affordable resin 3D printers use LCD masking to solidify layers.

1.2.1.5 Multi jet fusion (MJF):

It is an 3D printing process that makes prototypes and end-use production parts. It exhibits fine feature resolution and good surface finishing. These parts have great strength and flexible compared to SLS parts. SLS uses laser to melt the materials used but in MJF we use fusing agent with heat to solidify.

Working:

- The printer head place a powder on the build platform and inkjet array head passes along the powdered layer and releases two types of liquid called fusing agent and detailing agent.
- A heat source passes the platform, where the fusing agent is present the layer starts melting and form a shape, the detailing agent remains same without melting to maintain dimensional accuracy.
- The loose powder is cleaned and remove the support structures.

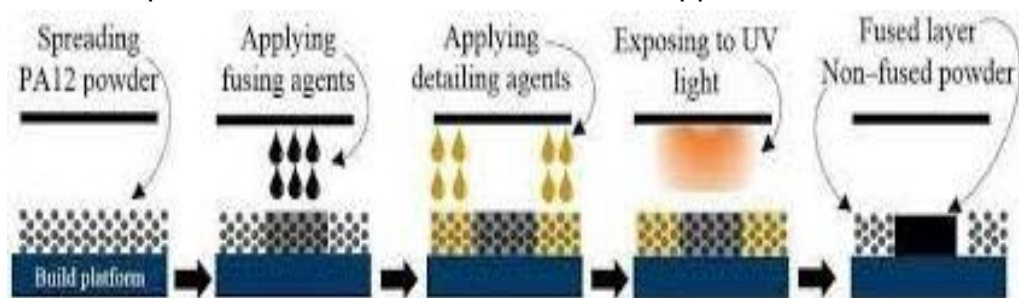


Fig 1.13 - MJF

- To complete the printing process, the printed bed is moved to separate place, the maximum unfused powder is removed by vacuum and recycled and used for another part.

Characteristics:

Table 1.4 – Characteristics of MJF

Materials	Nylon
Layer thickness	Normal resolution (80 microns)
Feature size	0.5 mm
Part size	284×380×380 mm
Tolerances	±0.25mm ±0.002mm

Pros and cons:

- It doesn't need any support structures.
- It prints different colors and good price quality ratio.
- It has short lead time and less wastage.
- Material options are low.
- It provides rougher surface.

These are the mostly used 3D printing technologies. By using these methods, we can create different geometrical dental implants and fillings in dentistry.

CHAPTER 2

The following survey is done to know about the methods and procedures present in the formation of tooth cap. Also, to know more about 3D printing and its techniques and applications and the properties and extraction of materials and their usages in the field of dentistry.

2.1 LITERATURE SURVEY:

2.1.1 Raquel couto de azevedo goncalves mota - 3D printing scaffold as a new perspective for bone tissue regeneration:

Due to the high incidence of bone fractures in the population, it became necessary to produce scaffolds that are able to assist in tissue regeneration. It is necessary to find an appropriate balance between the mechanical and biological properties, in order to mimic the natural tissue, these properties are directly related to the architecture and their degree of porosity, as well as the size of their pores and their interconnectivity.

In this perspective, the 3D printing stands out, where the structure is obtained layer by layer, according to a predetermined computational model which provides a greater control of architecture and scaffold geometry and overcomes, in this way, the limitations of traditional techniques of scaffolds manufacturing. In this way, the objective of this seminar is to present the state of the art of the polymer scaffolds produced by 3D printing and applied to bone tissue regeneration, highlighting the advantages and limitations of this process.

The importance of porosity in the study of polymeric scaffolds used in bone tissue engineering is fundamental, since it directly changes its permeability to nutrients, its mechanical properties and its biodegradation kinetic. For this reason, the advent of 3D printing allows us to overcome limitations of traditional scaffolds manufacturing techniques, because the structure is built layer by layer, according to a predetermined computer model, which provides better control of the scaffold's architecture and geometry.

Hence, it is possible to vary, with a certain amount of accuracy, the porosity degree, the size of the pores and their interconnectivity, aiming to achieve the ideal balance

between mechanical support and mass transportation and to maximize the scaffolds function of guiding and stimulating tissue repair.

2.1.2 A Jemat, M J Ghazali - Surface modifications and their effects on titanium dental implants:

This review covers several basic methodologies of surface treatment and their effects on titanium implants. The importance of each treatment and its effects will be discussed in detail in order to compare their effectiveness in promoting osseointegration. Published literature for the last 18 years was selected with the use of keywords like titanium dental implant, surface roughness, coating, and osseointegration.

Significant surface roughness played an important role in providing effective surface for bone implant contact, cell proliferation, and removal torque, despite having good mechanical properties. Overall, published studies indicated that an acid etched surface-modified and a coating application on commercial pure titanium implant was most preferable in producing the good surface roughness. Thus, a combination of a good surface roughness and mechanical properties of titanium could lead to successful dental implants.

It is clearly noted that by altering or modifying the surface texture, namely, the roughness of titanium implants, in particular, desired effects can be obtained like bone implant contact, removal torque values, tissues response.

Thus, most works still favour surface treatment of dental implants via coating and acid etching over other methods in producing good substrate surfaces for osseointegration, with surface roughness ranging from 0.44 to 8.68 μ m. In short, a good surface with the right roughness and mechanical properties could lead to better osseointegration for successful dental implants.

2.1.3 Mutlu ozcan, Christoph hammerle - Titanium as a reconstruction and implant material in dentistry advantages and pitfalls:

Commercial pure titanium has been the material of choice in several disciplines of dentistry due to its biocompatibility, resistance to corrosion and mechanical properties. Despite a number of favorable characteristics, Commercial pure titanium as a

reconstruction and oral implant material has several shortcomings. This paper highlights current knowledge on material properties, passive oxidation film formation, corrosion, surface activation, cell interactions, biofilm development, allergy, casting and machining properties of commercial pure titanium for better understanding and potential improvement of this material for its clinical application. Both titanium and titanium alloys, based on their physical, chemical and biological properties, appear to be especially suitable for dental implants and prostheses.

For the construction of implant devices, titanium and its alloys have become well-accepted and can be considered the materials of choice. Surface activation or tuning of titanium surfaces certainly will improve biological integrity in compromised situations, increasing clinical service of implant therapies even further. Processing difficulties, however, have limited usefulness of titanium in fixed and removable prostheses in dentistry. For crown and bridge prostheses, dentists can consider titanium and its alloys as viable options to more traditional noble and base metal alloys, but careful selection of processing methods and laboratory skill are necessary to ensure success.

2.1.4 A Kessler, R Hickel - 3D printing in dentistry:

Three-dimensional (3D) printing is a rapidly developing technology that has gained widespread acceptance in dentistry. Compared to conventional (lost-wax technique) and subtractive computer numeric controlled methods, 3D printing offers process engineering advantages. Materials such as plastics, metals, and ceramics can be manufactured using various techniques. 3D printing was introduced over three decades ago.

Today, it is experiencing rapid development due to the expiration of many patents and is often described as the key technology of the next dependent on the available materials, which must not only provide the required accuracy but also the necessary biological and physical properties.

The aim of this work is to provide an up-to-date overview of the different printing techniques: stereolithography, digital light processing, photopolymer jetting, material jetting, binder jetting, selective laser sintering, selective laser melting, and fused filament fabrication. Additionally, particular attention is paid to the materials used in

dentistry and their clinical application.

2.1.5 Helena Dodziuk - Applications of 3D printing in health care:

3D printing is a relatively new, rapidly expanding method of manufacturing that found numerous applications in healthcare, automotive, aerospace and defense industries and in many other areas. In this review, applications in medicine that are revolutionizing the way surgeries are carried out, disrupting prosthesis and implant markets as well as dentistry will be presented.

The relatively new field of bioprinting, that is printing with cells, will also be briefly discussed. 3D printing (3DP) developed as a modification of an old inject printer. Today, it is rapidly expanding: almost every week new printers and printing materials offering novel possibilities as well as new exciting applications appear. Healthcare, automotive, aerospace and defense industries are the most vivid areas of 3DP applications. The review will present applications in medicine that are revolutionizing the way operations are carried out, disrupting prosthesis and implant markets as well as dentistry, to name but a few. The relatively new field of bioprinting, that is printing with cells, will also be briefly discussed.

As will be presented below, numerous applications of 3DP in medicine belong to personalized medicine. For instance, implants or prostheses are 3D printed for a specific user's body, optimizing the technology to work for an individual, not an average user as with most mass-produced products. It should be stressed that contrary to better known cases of personalized medicine dealing with molecules of drugs and their corresponding active sites.

2.1.6 Leonardo Fernandes da Cunha - Cosmetic remodeling of the smile: combining composite resin and ceramics over teeth and implants:

The aim of this paper is to describe a restorative approach to the cosmetic remodeling of the teeth of a young adult patient with right maxillary lateral hypodontia and left lateral microdontia. A conservative restorative management was proposed to improve smile esthetics by combining direct composite resins and ceramics. Initially, periodontal therapy and dental bleaching were performed. Subsequently, direct composite resins were applied to the central incisors and canines to reestablish the sizes and shapes of these teeth. Finally, ceramics were placed on the implant and the

microdontia to unite with the new alignment and color of the anterior teeth. Thus, conservative remodeling to improve the harmony of the smile was provided. In cases of single implant prostheses used on anterior teeth, it is always an aesthetic challenge to match these restorations with the other teeth. In the case presented, the initial image showed the higher opacity of this restoration.

To favour aesthetics, a restoration with a zirconia structure was used to mask the metal and to facilitate the characterization of the overlying ceramic. The aesthetics and longevity of the Emax system were widely reported in the literature, supporting its choice for the case in question. Thus, the association of composite resins and ceramics after periodontal treatment and tooth whitening for remodelling a smile is a conservative, efficient, and safe approach to aesthetic improvement.

2.1.7 Yueyi tian, chunxu chen - A review of 3D printing in dentistry, technologies, affecting, factors and applications:

Three-dimensional (3D) printing technologies are advanced manufacturing technologies based on computer-aided design digital models to create personalized 3D objects automatically. They have been widely used in the industry, design, engineering, and manufacturing fields for nearly 30 years. Three-dimensional printing has many advantages in process engineering, with applications in dentistry ranging from the field of prosthodontics, oral and maxillofacial surgery, and oral implantology to orthodontics, endodontics, and periodontology.

This review provides a practical and scientific overview of 3D printing technologies. First, it introduces current 3D printing technologies, including powder bed fusion, photopolymerization molding, and fused deposition modeling. Additionally, it introduces various factors affecting 3D printing metrics, such as mechanical properties and accuracy. The final section presents a summary of the clinical applications of 3D printing in dentistry, including manufacturing working models and main applications in the fields of prosthodontics, oral and maxillofacial surgery, and oral implantology.

The 3D printing technologies have the advantages of high material utilization and the ability to manufacture a single complex geometry; nevertheless, they have the disadvantages of high cost and time-consuming postprocessing. The development of new materials and technologies will be the future trend of 3D printing in dentistry, and

there is no denying that 3D printing will have a bright future.

2.1.8 Bing wang, chuwen fang - The effect of 3D printing metal materials on osteoporosis treatment:

3D printing has been in use for a long time and has continued to contribute to breakthroughs in the fields of clinical, physical, and rehabilitation medicine. In order to evaluate the role of 3D printing technology in treating spinal disorders, this paper presents a systematic review of the relevant literature.

3D printing is described in terms of its adjunctive function in various stages of spinal surgery and assistance in osteoporosis treatment. A review of metal 3D printed materials and applications of the technology is also provided. Surgeon in the field of spine surgery needs to have a strong background in anatomy. Medical education is being aided by 3D printed spine models.

3D printed spine fracture models can help physicians identify complex spine fracture markers, practice prior to spine surgery, and develop standardized training programs. Plaster molds or specially treated cadaveric bones are the most common models for teaching spinal anatomy. However, plaster molds are not very accurate and are single models, and cadaveric bones are not always easily available and are vulnerable to ethical or legal issues randomly assigned 62 orthopedic residents to one of two groups.

The control group learned about scoliosis using conventional methods, while the experimental group received additional training using 3D printed models. The experimental group was more successful than the control group in assessing the parietal vertebrae in scoliosis patients. as well as in identifying the structures that needed to be surgically repaired and fused. The experimental group also scored higher than the control group on interest in learning, learning efficiency, interactions with the teacher, and teamwork ability measures.

3D printing is still an emerging technology; however, relevant regulations have not yet been perfected, clinical applications are limited due to high costs, and it has not yet been applied widely outside of a few complex cases. Nevertheless, with recent emphasis on innovative medical technologies, the utility of raw materials for 3D printing has increased, the costs are decreasing, and efficacy is improving.

2.1.9 Babak sarrafpour - Tooth eruption results from bone remodeling driven by bite forces sensed by soft tissue dental follicles:

Intermittent tongue, lip and cheek forces influence precise tooth position, so we here examine the possibility that tissue remodeling driven by functional bite-force-induced jaw-strain accounts for tooth eruption. Notably, although a separate true 'eruptive force' is widely assumed, there is little direct evidence for such a force. We constructed a three-dimensional finite element model from axial computerized tomography of an 8 years old child mandible containing 12 erupted and 8 unerupted teeth.

Tissues modelled included: cortical bone, cancellous bone, soft tissue dental follicle, periodontal ligament, enamel, dentine, pulp and articular cartilage. Strain and hydrostatic stress during incisive and unilateral molar bite force were modelled, with force applied via medial and lateral pterygoid, temporalis, masseter and digastric muscles. Strain was maximal in the soft tissue follicle as opposed to surrounding bone, consistent with follicle as an effective mechanical sensor. Initial numerical analysis of dental follicle soft tissue overlying crowns and beneath the roots of unerupted teeth was of volume and hydrostatic stress.

To numerically evaluate biological significance of differing hydrostatic stress levels normalized for variable finite element volume, 'biological response units' in Nm. It is calculated by multiplication of hydrostatic stress and volume for each finite element. Graphical representations revealed similar overall responses for individual teeth regardless if incisive or right molar bite force was studied. There was general compression in the soft tissues over crowns of most unerupted teeth, and general tension in the soft tissues beneath roots.

Not conforming to this pattern were the unerupted second molars, which do not erupt at this developmental stage. Data- support a new hypothesis for tooth eruption, in which the follicular soft tissues detect bite-force-induced bone-strain, and direct bone remodeling at the inner surface of the surrounding bony crypt, with the effect of enabling tooth eruption into the mouth.

2.1.10 Soroush trandout, S Muftu - The interplay between bone healing and remodeling around dental implants:

Long-term bone healing/adaptation after a dental implant treatment starts with

diffusion of mesenchymal stem cells to the wounded region and their subsequent differentiation. The healing phase is followed by the bone-remodeling phase. In this work, a mechano-regulatory cellular differentiation model was used to simulate tissue healing around an immediately loaded dental implant. All tissue types were modeled as elastic in the healing phase.

Material properties of the healing region were updated after each loading cycle for 30 cycles (days). The tissue distribution in the healed state was then used as the initial condition for the remodeling phase during which regions healed into bone adapt their apparent density with respect to a homeostatic remodeling stimulus. The short-term (bone healing) and long-term (bone remodeling) effects of initial implant micromotion during the healing phase were studied.

Development of soft tissue was observed both in the coronal region due to high fluid velocity, and on the vertical sides of the healing-gap due to high shear stress. In cases with small implant micromotion, tissue between the implant threads differentiated into bone during the healing phase but resorbed during remodeling.

In cases with large implant micromotion, higher percentage of the healing region differentiated into soft tissue resulting in smaller volume of bone tissue available for remodeling. However, the remaining bone region developed higher density bone tissue. It was concluded that an optimal range of initial implant micromotion could be designed for a specific patient in order to achieve the desired long-term functional properties.

2.1.11 Jabr S. Al-Sanabani, Ahmed A. Madfa - Application of calcium phosphate materials in dentistry:

Calcium phosphate materials are similar to bone in composition and in having bioactive and osteoconductive properties. Calcium phosphate materials in different forms, as cements, composites, and coatings, are used in many medical and dental applications. This paper reviews the applications of these materials in dentistry. It presents a brief history, dental applications, and methods for improving their mechanical properties. Notable research is highlighted regarding (1) application of calcium phosphate into various fields in dentistry; (2) improving mechanical properties of calcium phosphate; (3) biomimetic process and functionally graded materials.

This paper deals with most common types of the calcium phosphate materials such as hydroxyapatite and tricalcium phosphate which are currently used in dental and medical fields. The article deals with some of the calcium phosphate materials which are currently used in dentistry and other calcium phosphate materials which have potential for dental applications.

Although, calcium phosphate materials excellent bioactive and osteoconductive properties that results in rapid bone formation in a host body and strong biological fixation to bony tissues, calcium phosphate materials possess low mechanical strength, which is an obstacle to its applications in load bearing areas. Thus, the enhancement of the mechanical properties of calcium phosphate materials would extend its scope of applications. Calcium phosphate materials are either used as a bioactive coating on implants or reinforced with tough phases such as metal or ceramic phases for biomedical/dental applications.

2.1.12 M Sumathra - Hydroxyapatite/pectin nanocomposite as filler material for dental applications:

Dental caries is a widespread chronic and world-wide oral disease. In dental treatment, composite biomaterials are used as fillers to restore teeth. A broad range of inorganic fillers are commercially available. Among them, hydroxyapatite [$\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$, HAP] can be widely used as biomaterial due to the chemical similarity to teeth. Therefore, synthetic HAP would seem a good choice as the inorganic filler to be used in dental restoration or bone implants. Concerning the human health and the environment, the use of hazardous materials is replaced by green chemical substances. The present study deals with a facile and efficient green route for the synthesis of HAP/pectin nanocomposite using pectin as a reinforcing material which was extracted from the peel of bitter orange fruits.

The pectin concentration involved in the synthesis plays a major role in the behaviour of crystallinity, purity, morphology as well as biological property of the as-synthesized HAP/pectin nanocomposite. The extracted pectin and the as-synthesized nanocomposite were characterized by various analytical techniques such as ^1H NMR, ^{13}C NMR, etc. The In vitro apatite formation on the surface of the as-synthesized nanocomposite in simulated body fluid for 7 days showed an enhanced bioactivity. The antimicrobial activity was investigated using various microorganisms. All the

results revealed the formation of pure, low crystalline and discrete granular like HAP/pectin nanocomposite with enhanced biological and antimicrobial activities. Hence the as-synthesized nanocomposite can act as a better filler material in the field of dentistry.

2.1.13 Rashmi Uddanwadiker - Study of various molar crown designs and their assessment:

Dental crowns are best utilized as a way to improve the cosmetics of a tooth appearance when the crown simultaneously serves other purposes also, such as restoring a tooth to its original shape or strengthening a tooth. The study presents four different designs of molar crown depending upon the tooth loss. The finite element results obtained suggests that restored material which fills the treated cavity along with small portion of root canal can help in retaining the restored tooth and can allow larger deformations for stresses induced well within the limit.

This investigation describes a rapid method for the generation of finite element models of dental structures and restorations. Detailed 3D finite element models of a molar Crown with different cavities and silver amalgam restorative materials were generated. Smaller cavities can be restored with strength quite close to that of natural crown. With a sufficient loss in tooth structure, retention capacity of foreign material in the restored tooth cannot be guaranteed. Few researchers [3,7] in past also performed similar studies and the results obtained by them closely matches the conclusion of the present study. Thus design-2 and design-4 results into better retention of the filling material.

CHAPTER 3

AIM AND SCOPE

3.1 *AIM:*

This project aims that, how 3D printing can be used in dental laboratories for making tooth cap to maximum extent. It attempts to present a rational evaluation of today's restoration; the project discusses future perspective and examines the ongoing viability of traditional dental laboratory services and manufacturing processes. It shows which expertise is needed for the digital additive manufacturing for dental restoration and case report of prosthetic treatment built upon 3D technologies for manufacturing of dental restoration, the article that are taken below are used as reference for our project, the article says about the 3D printings used in different field such as bone tissue regeneration and also uses in the dentistry. 3D printing is the innovative method of acquiring the exact same image. The aim of the project is also to avoid the metal and alloys in making of the crowns, instead to use bio-ceramics to co polymer as a biocompatible for tooth cap. CAD software is used to design and simulate the tooth cap in viable environment such that there is no miscible after the implementation.

3.2 *SCOPE:*

Above research of papers on teeth and crowns, is to know more about the teeth, it's diseases and at what position of decay crowns are used and what are the procedures(types) and defects of crowns. By using this content, we can make sure of the natural materials that are good with teeth and won't cause any diseases further because of crown. Also, to reduce the effects that are producing by the other crowns that are available in the present market. We researched about the materials that are compatible with the body and teeth and picked them and understood about the properties of the materials. So that we can use them for the particular needs that are required for us and chosen materials forms a rigid shape and body to the crown.

Research about 3D printing or CAD software gave us the whole knowledge about the techniques, usage of software too. By using, software we are able to design the tooth cap in required dimensions. 3D printing is vast and we selected the 3D printing technique based on the product to be formed. Making a product in a particular method

results in the good output and cost efficient too. We thoroughly learnt about the pros and setbacks of the different methods in 3D printing. We decided to use ANSYS software for the simulation of the design. In the process of research, we came to know that Ansys software provides accurate and standard results in the stability and strongness of the product.

CHAPTER 4

MATERIALS AND METHODS:

4.1 MATERIALS:

We are using bio-ceramics and Co-polymer as biocompatible materials in the preparation of tooth cap. The biomaterials are non-toxic, biodegradable or inflammatory responses within the human body and it has low water absorption which tends to have minimal or no damage to the tooth cap.

4.1.1 Biomaterials:

Biomaterials are naturally or synthetically derived materials, which are widely used in medical approaches to enhance, support or protect, restore damaged tissue or its biological function. These biomaterials are used in medical implants, promoting healing of human tissues, regeneration of human tissues, molecular probes, biosensors and drug delivery systems.

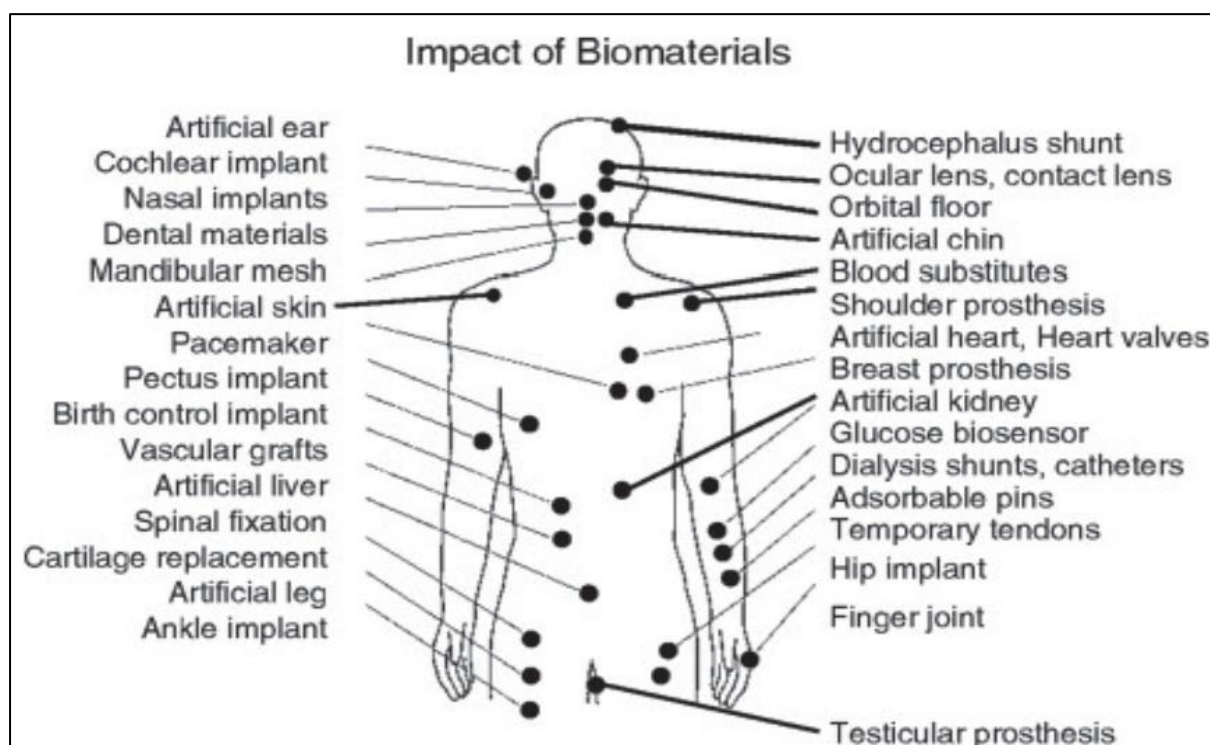


Fig 4.1 – Impact of biomaterials

Depending on bond between the chemical compound materials are classified into three major groups – Polymers, Ceramics and Metals. The structures of material change by nature of bonding.

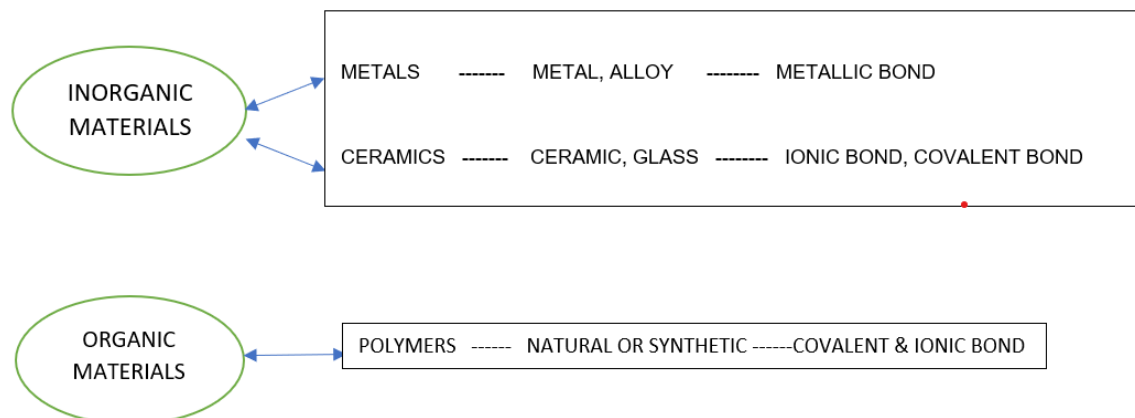


Fig 4.2 – Types of biomaterials

4.1.2 Biopolymers:

Biopolymers are the organic biomaterials and these are obtained from the natural sources. These can be formed from biosynthesized by living substances or chemically synthesized from biomaterials.

These biopolymers are extracted from the plants and microorganisms, they are reusable resources. They contain monomer units bonded together by ionic and covalent bonds to form large molecules.

Biopolymers are renewable and maintainable resources and easily degradable and they are non-toxic, they are available in plenty and perform same characteristics and Non-carcinogenic and Nonimmunogenic.

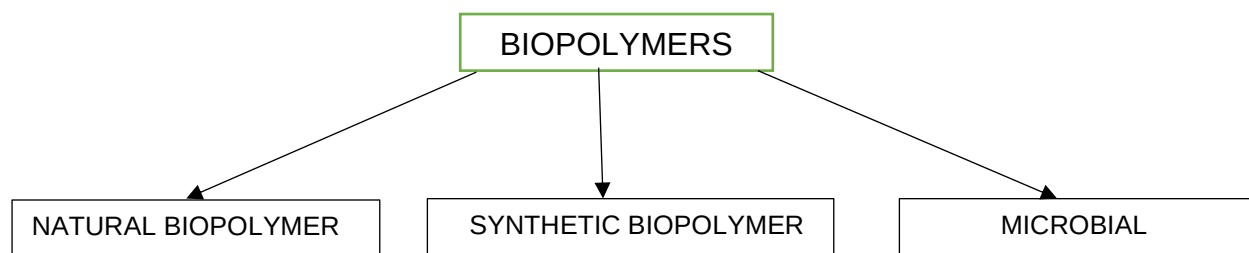


Fig 4.3 – Types of biopolymers

In project, we are using the biopolymer POLYVINYLPYRROLIDONE as one of the chemical components in the preparation of tooth crown or fillings.

4.1.2.1 Polyvinylpyrrolidone:

Polyvinylpyrrolidone (PVP) is normally called as povidone or polyvidone. It is a synthetic polymer which contains 1-vinyl-2-pyrrolidone groups. It is a water-soluble polymer. PVP doesn't contain any definite shape or form and it is hygroscopic in nature. PVP is non-toxic, inert, biocompatible, biodegradable which helps to confine and victual both lipophilic and hydrophilic groups, it is able to combat great heat and pH-stable.

Polyvinylpyrrolidone is used in dentistry mainly to stop stains and coloration on tooth enamel. It acts as suspending agent in growing of stains.

Chemical structure:

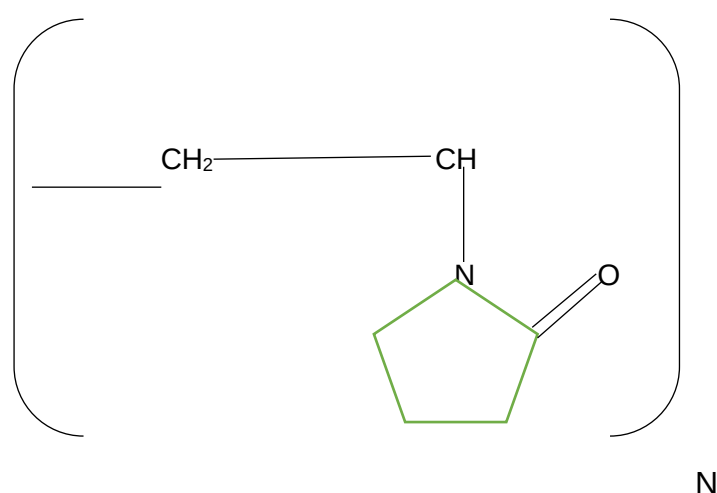


Fig 4.4 – Chemical structure of PVP

4.1.3 Bio-ceramics:

Bio-ceramics are the materials that are used for repairing the damaged tissues. Bio-ceramics are biocompatible materials. They are interactive with surrounding and either supportive tissue growth or regeneration of ceramics. They are antibacterial, anticorrosive, dimensionally stable and inert. They're used to make a hard bond to bone and made as an alternative for metal implants. bio-ceramics are classified according to their composition and their responses. They're made into three types:

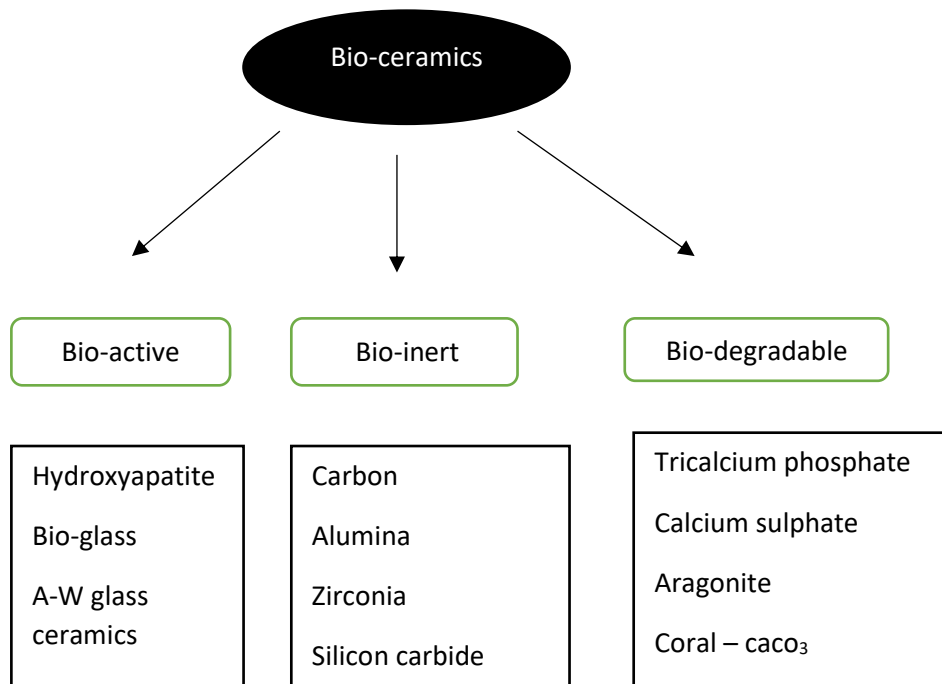


Fig 4.5 – Types of bio-ceramics

4.1.3.1 β -tricalcium phosphate:

beta-tricalcium phosphate is the most preferred and powerful synthetic bone graft substitute. It is the ceramic used treat bones defects created by teeth and the calcium phosphate rules the distribution of calcium and phosphate ions to the teeth. B-TCP is more stable and very biocompatible material.

It is calcium salt of phosphoric acid and it is white powder which is tasteless and odorless. It is soluble in water and TCP water solubility reduces when it is at high temperatures. It is stable and chemically reactive. It is non-toxic and is used as food additive in limit levels. It`s density is about 3.14g/ml and melting point is 1940 K.

Chemical formula:

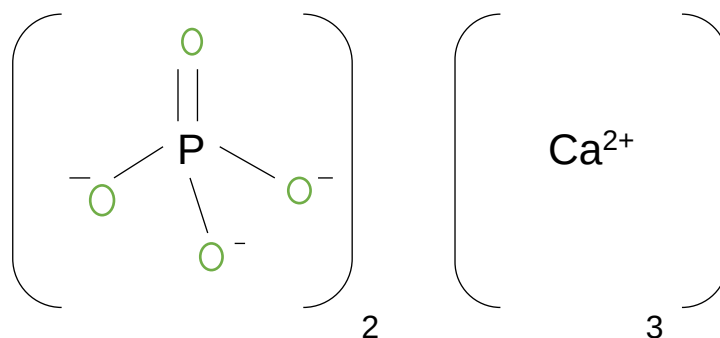


Fig 4.6 – Chemical structure of TCP

4.1.4 Chitin:

Chitin is named as highly biocompatible biopolymer because of its bioactivity, bio-adhesivity and biodegradability. It is a sweet sugar substance that extracted from the external skeleton of lobster, shellfish and shrimp and including lobster. It works as a strong protective outer covering layer and gives support. The main function of chitin is preventing the teeth from caries and acts as antimicrobial agent. It also used in the field of conservative dentistry surgery.

Chemical formula: $(C_8H_{13}O_5N)_n$.

4.1.5 Pectin:

Pectin is a natural polymer. It is a pack of polysaccharides which is rich of galacturonic acid. It is derived from the various plant like peel of citrus fruit, papaya and sunflower heads etc. it is used as gelling agent and stabilizer for food and emulsifier. The main reason of using the pectin is to increase the stability of teeth and it can be used as main filling substance in dentistry.

Chemical formula: $(C_6H_{10}O_7)$.

4.1.6 Magnetic stirrer:

Magnetic stirrer will use the rotating magnetic field and make the stir bar to move around the solution or samples and the samples are mixed thoroughly by the movement of stir bar with rapid movement and churning. The user will set the speed of magnetic field needed based upon the sample placed. We should use stirrer glass or non-metal beakers to avoid interference with magnetic field.

A bead magnet is placed inside the container, submerged in fluid. And when we set the speed in RPM and then the bead inside the container will start rotating in the beaker this is because there will be a magnetic present in the underneath the container (or plate). The lower magnet normally connected to the motor and start spins when we give some speed.



Fig 4.7 – Magnetic stirrer

Main use of magnetic stirrer or magnetic stirrer with hot plate is to mix different components in conducting experiments. It is commonly suitable for liquid or solid samples to get a constant liquid mixture.

4.2 METHODS:

4.2.1 Sample preparation:

The theme of the project is to do tooth cap using bio-ceramics and biopolymers. We considered some biomaterials which are suitable and habitable to last long without any effect and drawbacks.

To know whether the chosen different materials will dissolve together and form a solution and remain durable and create a sample for formation of tooth cap is determined by undergoing experiment.

4.2.1.1 Chitin sample:

Materials: polyvinylpyrrolidone, beta-tricalcium phosphate, chitin, water Solution, magnetic stirrer, bead, butter paper, glass beaker and weighing machine.

Procedure:

- First, place the magnetic stirrer (1MLH Remi) on the table.
- Connect to the current source near to it and on the machine.
- Clean the magnetic bead which should be placed inside the beaker.
- Take the glass beaker and fill it with 50ml of water in it and place it on magnetic stirrer and place the magnetic bead in it.
- Leave it for 5 minutes at the 600 RPM and let it heat.
- Place the butter paper on the weighing machine and make it 0g.
- Then measure 0.5g of polyvinylpyrrolidone and add it to the beaker for every 15 minutes for thrice at 800 RPM.
- Leave the beaker for 20 minutes to dissolve with water.
- After PVP is dissolved, take beta-tricalcium phosphate of 3g (always β -TCP is double the PVP) and add 1g β -TCP for the above solution for every 15 minutes for thrice at 900-1000 RPM. Let the solution get dissolved. Leave it for 20 minutes.
- Take 3gm of chitin and add it to the above solution slowly as 1g for every 10 minutes at same RPM as mentioned above.
- Let it get stirred for 40 minutes.
- After 40 minutes, we observed that chitin is not dissolved with the PVP and β -TCP.



Fig 4.8 – chitin sample

We concluded that, by adding chitin to PVP and β -TCP we didn't get a slurry or gel form of sample. It is due to chitin have poor solubility limits and it is insoluble in all

regular solvents. Chitin is highly aggregated. So, it won't dissolve easily. It is time consuming process.

4.2.1.2 Pectin sample:

Materials: polyvinylpyrrolidone, Beta tricalcium phosphate, pectin, water solution, magnetic stirrer, magnetic bead, butter paper, glass beaker and weighing machine.

Procedure:

- First, place the magnetic stirrer (1MLH Remi) on the table and connect to the current source near to it and on the machine.
- Clean the magnetic bead which should be placed inside the beaker.
- Take the glass beaker and fill it with 50ml of water in it and place it on magnetic stirrer and place the magnetic bead in it.
- Leave it for 5 minutes at the 600 RPM and let it heat.
- Place the butter paper on the weighing machine and make it 0g.
- Then measure 0.5g of polyvinylpyrrolidone and add it to the beaker for every 15 minutes for thrice at 800 RPM.
- Leave the beaker for 20 minutes to dissolve with water.
- After PVP is dissolved, take beta-tricalcium phosphate of 3g (always β -TCP is double the PVP) and add 1g β -TCP for the above solution for every 15 minutes for thrice at 900-1000 RPM. Let the solution get dissolved. Leave it for 20 minutes.
- Take 3gm of Pectin and add it to the above solution slowly as 1g for every 10 minutes at same RPM as mentioned above.
- Let it get stirred for 40 minutes.
- After 40 minutes, we observed that pectin is dissolved with the PVP and β -TCP.

From the above formed solution, we came to conclusion that, Pectin is dissolved in PVP and β -TCP solution. Pectin is formed because it is water soluble in nature and formed a pure gel. Using pectin acts as a protective strong layer for tooth cap.



Fig 4.9 – Pectin sample

In above we performed, same way of experiments on two biopolymers to know which one is suitable and effective for making of tooth cap. by using pectin we can make the product so hard and time effective too.

Pectin sample had sent to the FTIR testing to know the sample composition.

4.2.2 Selective laser sintering (SLS):

Selective laser sintering is type of technique in 3D printing. It is an additive manufacturing (AM) technology which makes powder particles into solid substance by using a great laser source based on 3D outlook. This is cheap, produce high quantity and they don't require support structures. This is best for functional prototyping and end-use production. The most materials used in SLS Is thermoplastic polymers that come in a form of granule.

Characteristics:

Table 4.1 – Characteristics of SLS printer

Materials	Thermoplastics
Dimensional accuracy	±0.3% (lower limit of 0.3 mm)
Build size	300×300×300 mm
Layer thickness	100 – 120 µm
Support	Not required

Working:

SLS printing uses a thin laser to sinter tiny particles of the polymer powder given. The entire dimensions of the component is scanned, so the component is built-in solid. The process is defined in three steps:

Printing:

- In the top of a platform which is in the build chamber a powder is dispersed in a thin layer.
- The powder placed on the platform is preheated at temperature below the melting point of the raw material.
- The laser scans the dimensions of 3D model and start heating the powder to the melting point.
- This makes the raw material particles to fuse and create a solid part.
- The unfused powder supports during printing and deny the need for support structures.
- The platform goes down by itself from one layer to another to build a structure and this process repeats until the structure is complete.
- The extra powder which is not fused with the part are removed with the fans present surrounded by the platform and the powder is stored and used for another part.

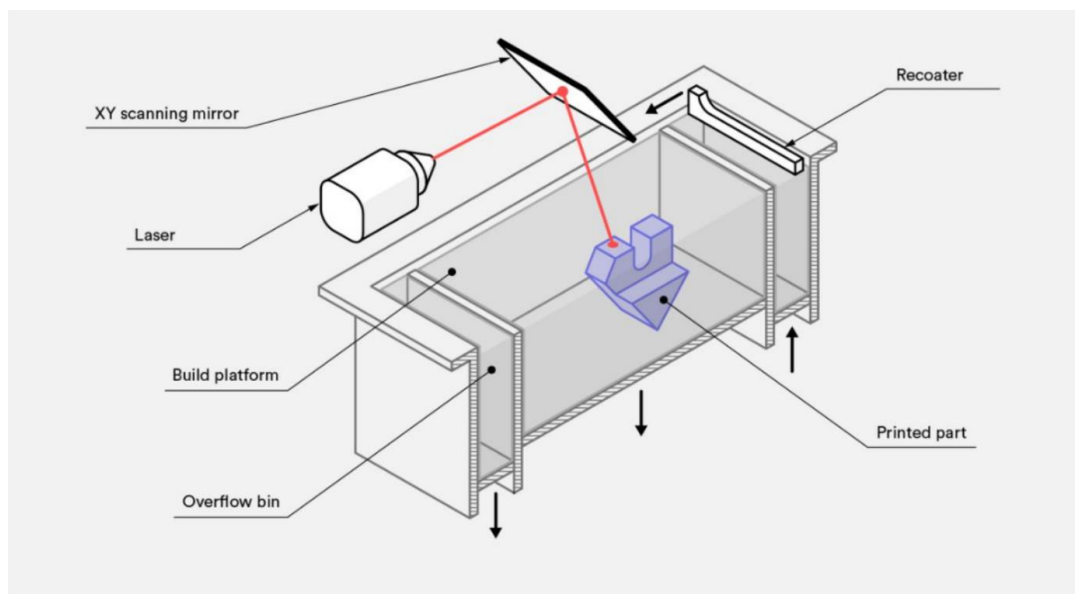


Fig 4.10 – SLS printer

Cooling:

- After the completion of printing, the build part should be cool down inside the print enclosure.
- The outside the printer should ensure that optimal properties and should avoid warping in structure.

Post-processing:

- The finished parts required to be taken out from the build chamber, segregated and washed off the extra powder.
- The extra powder is recycled and the parts printed are further post processed by media tumbling.

It results in the formation of hard and fragile product but this modeled by using the vacuum. The dentist will take the dimensions of the particular teeth of the patient and the model is designed in the software and the design is printed in the SLS technique using the process.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 SAMPLE PREPARATION RESULTS:

Table 5.1 – Composition in sample

S.NO	H2O	Beta-TCP	Pectin	PVP	Chitin
A1.	50ml	3g	3g	0.5g	3g
A2.	50ml	3g	1.5g	0.1g	-
A3.	50ml	3g	2g	0.25g	-
A4.	50ml	3g	2.5g	0.4g	-
A5.	50ml	3g	3g	0.5g	-

Bone filling is an artificial bio-degradable substance, implanted in our body to repair and able to regenerate tissue growth in an injured or infected part of tooth. Numerous materials are available such as chitin, pectin, alginate, gelatin, poly lactic acid, and so on. As shown in Table 1, five samples (A1, A2, A3, A4, A5) with different combinations of Beta-tricalcium phosphate, pectin and PVP were prepared to standardize the bone filling slurry using wet chemical method.

Among the samples used to prepare the bone filling, sample A4 & A5 exhibited a perfect slurry combination than the other combinations. Hence A4 & A5 sample ratios was considered as an ideal combination for preparation of bone filling. Therefore, A5 sample was subjected to further characterization studies.

Beta-tricalcium phosphate which mimics body calcium phosphate component and enrich our cell proliferation. Pectin gives a good potential strength to support the re-growth of the tissue. Slurry consistency gives its unique support to the cell proliferation around the cells. The standardized ratio of bone filling preparation is given in table 1.

The sample prepared is given for the FTIR testing to know the composition of the materials in it. The results are given below:

5.1.1 Analytical Characterization:

FTIR spectral analysis of tooth filling slurry was represented in Fig Beta-tricalcium phosphate exhibits the characteristic peak bands of phosphate group (PO_4), pectin, PVP and water. The peaks at 1000cm^{-1} and 550cm^{-1} are assigned to vibrations of phosphate group, PO_4 (pang et al., 2016).

The phosphates have double bond group PO_4 form intensive IR absorption bands at 800cm^{-1} to 400cm^{-1} and 1000cm^{-1} . The FTIR absorption band of beta tri-calcium phosphate peaked at 1050cm^{-1} and it contain calcium, phosphorous and oxygen groups. The peak corresponding to the bending mode of O-P-O bonds falls on 550cm^{-1} . The absorption bands of amide I and amide II related to pectin group observed in the spectra of the slurry composite.

Giada et al., 2013, observed that the IR spectral study of pectin band peaked at 1800cm^{-1} C=O stretch corresponding to amide I group. In the present study the absorption band of the amide I and amide II related to pectin can observed in the FTIR spectra of tooth filling slurry. The bands are generally larger due to the macro and micro molecular structure of the compound containing numerous intermolecular bindings.

5.1.2

FTIR

Wavelength	Chemical Bond	Functional Group
3400-3200	N-H stretch, O-H stretch, free hydroxyl	1°, 2° amines, amides, alcohols, phenols
1800-1500	C=O stretch	carboxylic acids
1500-1000	C-C stretch (in-ring), C-O stretch	Aromatics, alcohols, carboxylic acids, esters, ethers
800-400	C-Cl stretch, -C α C-H: C-H bend	alkyl halides, alkynes

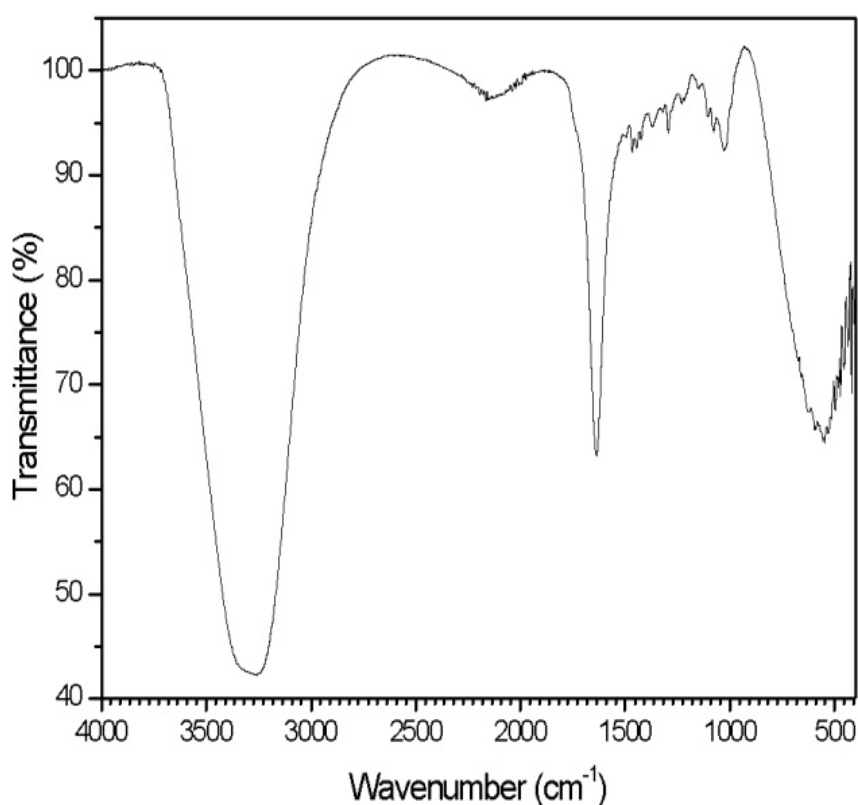


Fig 5.1 – FTIR results

5.2 DESIGN OF TOOTH CAP:

To make a tooth cap, first we have to construct a design of tooth cap. It is very difficult to make a design of tooth cap in 3D because the dimensions and structure of the tooth should be aligned properly without any errors. So, we can make a definite structure what we are hoping for. We use RHINO software for modelling of tooth cap.

5.2.1 Rhino 3D software:

Rhino can create, analyze, render, edit, translate NURBS curves, Sub-D and polygon mesh. There are no limits on degree or size beyond hardware. We can create any type of shape and size by using the tools in it. They are uninhibited, accurate, compatible, easily accessible, fast to learn and affordable.

Rhino software is a computer aided design application which is used to do a prototyping on any structure or design. It is based on 3D and 2D concepts and it is good for 3D models. It contains all types of tools from points to all type of curves and solids and surfaces too. In user interface, it has all types of commands, construction aids and background bitmaps etc.

This software is used in dental laboratories. This allows to create aesthetic and durable prostheses for patients. It will increase the simplicity of design and making restorations. It enables the dentist to create a full design in less time. This system will use a camera to take a digital impression by constructing a 3D image which is imported into program and results in computer cast in which design is restored.

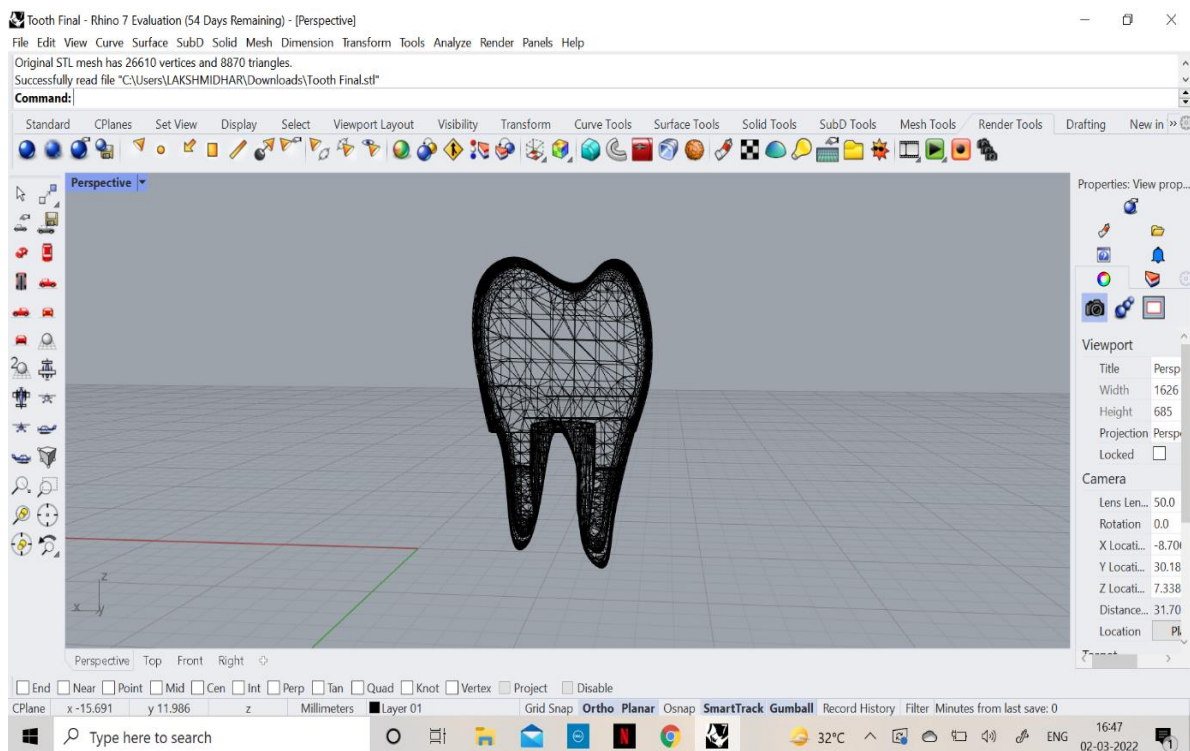


Fig 5.2 – Design of tooth in rhino

By using this software, we constructed the design of tooth cap with definite dimensions. The created design should go under simulation to know the base strength of the design is perfect or not.

5.3 SIMULATION RESULTS:

The tooth designed from rhino software should be given for simulation testing to know whether the design is standard and strong at certain pressure and situations. For simulation, Ansys software is used.

5.3.1 Ansys software:

Ansys software is a ANALYSIS SYSTEM. It is a CAD software used to design and evaluate the concepts and topologies, to know the performance of the designed product and the efficiency and the product stability and strongness.

Ansys software used for learning the machine or product components for analyzing the toughness, elasticity, strength, temperature efficient, fluid flow and etc. it is used to know how the structure is functioning in different conditions and atmosphere. All the simulations in Ansys are done by using Ansys workbench system. In this, the design or structure are breakdown and separated into different parts and they start examining the breakdown parts individually. They start the process by defining the length and breadth of the object and further by adding pressure, weight and other physical properties. At start they simulates and determine the movement, distribution of heat and fluid flow and other mechanical properties too. This software gives a chance to provide the technology at any level of discussion about the product.

By using this software, the designed tooth is going under simulation to know the strength and physical properties of it.

Stress:

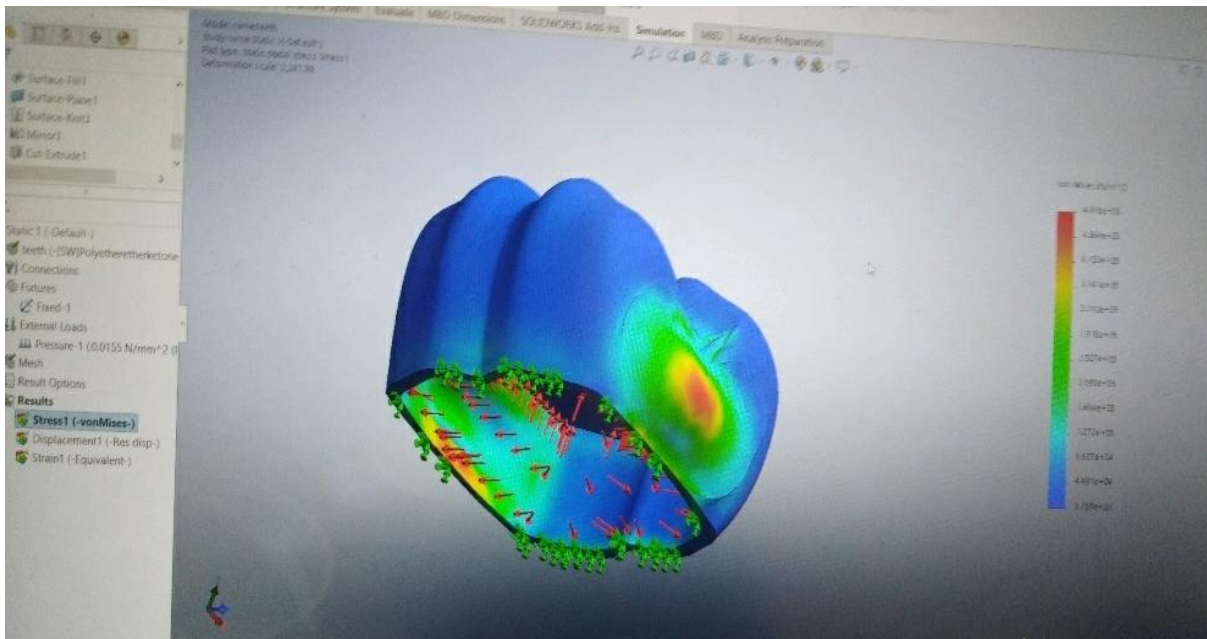


Fig 5.3 – Stress in Ansys

Shows the deformation of the tooth when a compression force of 0.0115 pascal is applied. As observed, PLA material tooth designed with maximum deformation of 4.9mm. This 3D tooth prototype with specific diameters have been acquired with the aid of using different scale elements and thickening factors.

Strain:

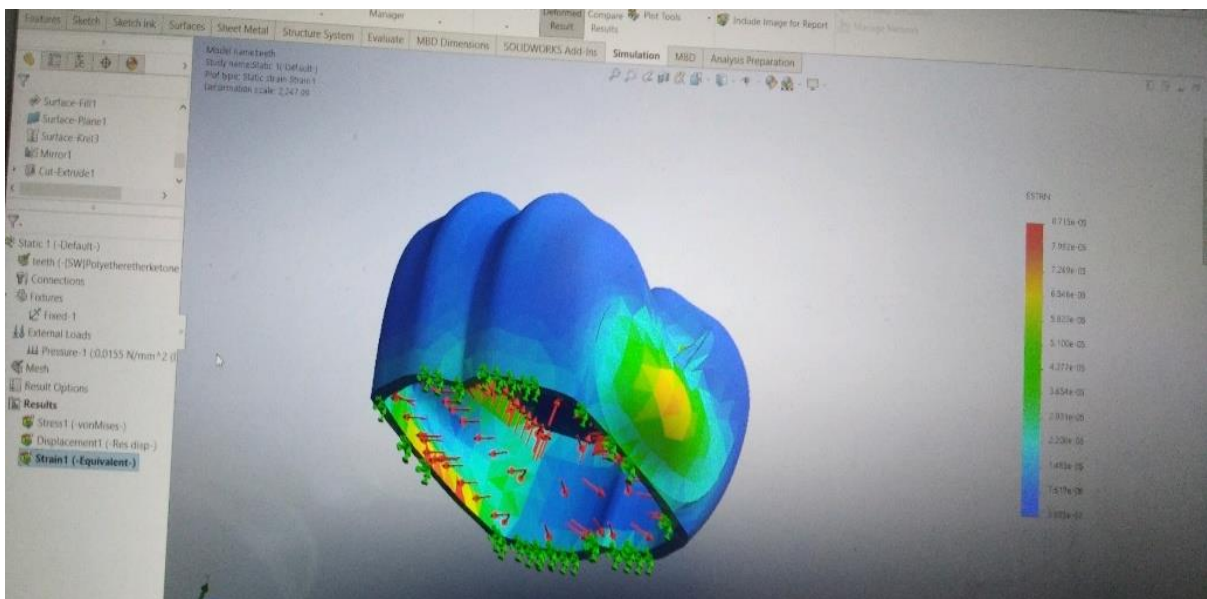


Fig 5.4 – Strain in Ansys

Displacement:

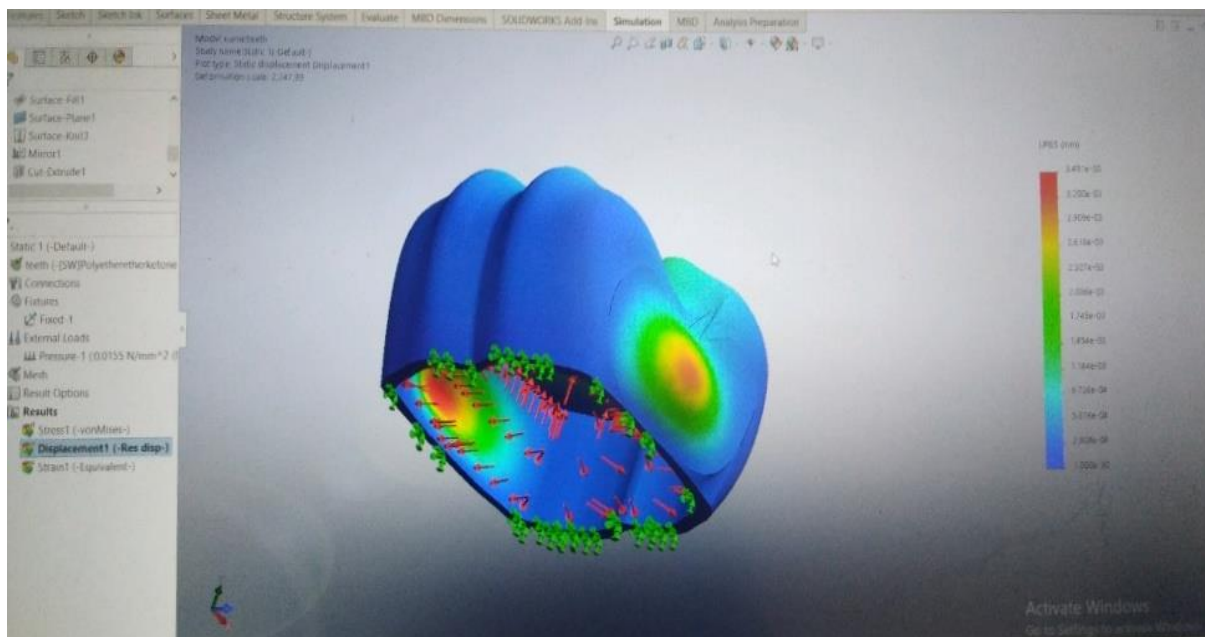


Fig 5.5 – Displacement in Ansys

As indicated by the research studies, the surface pressure impacts the cell proliferation than the liquid pressure, however the inlet strain influences the mass flow of the nutrient fluid in a tooth without any delay. Based on the outcomes, it appears to be that tooth design in PLA material (testing) for dental applications because of the great deformity and therefore, to the spreading of cells to the internal region of the tooth and the supply of sufficient oxygen and nutrients.

CHAPTER 6

CONCLUSION:

The project aims to make a tooth cap using 3D printing with the compositions of biomaterials like beta tricalcium phosphate, polyvinylpyrrolidone and pectin. By the combination of the above materials, we formed a gel structure and the compositions in the gel are tested with FTIR. The results show that the gel contains all the required composites in it. Which makes the tooth cap strong, durable, low cost and the most sold tooth cap and the best tooth cap present in the market are porcelain tooth cap. These are made by ceramics only to look like natural teeth. the main disadvantage of using porcelain materials are they get coloration fast and fragile and sensitivity. But by using the polyvinylpyrrolidone teeth won't get colored easily and stops from getting irritation in gums. TCP makes the hard structure and strong tooth cap then the porcelain tooth cap. Pectin is used to stand by as the protective layer for teeth. So, by using these natural biomaterials we can make the tooth cap in best quality. By using 3D printing, we can make the production of tooth cap faster than present. Patients no need waiting for long time and making two visits with dentists are not necessary. We can design them after taking the patients dimensions and printing it will take few hours, we can make bulk amount of production too.

CHAPTER 7

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