DESIGN OF 3D PRINTER FOR DENTAL DESIGN AND FABRICATION

A DISSERTATION

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE
of
MASTER OF TECHNOLOGY
in
SIGNAL PROCESSING AND DIGITAL DESIGN

Submitted By
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(2020/SPD/11)

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CANDIDATE'S DECLARATION

I, Rishav K Sharma, 2020/SPD/11 of M.Tech hereby declare that the project Dissertation titled "**DESIGN OF 3D PRINTER FOR DENTAL DESIGN AND FABRICATION**", which is submitted by me to the Department of Electronics & Communication Engineering, Delhi Technological University, Delhi in the partial fulfilment of the requirements for the award of the degree of **Masters of Technology** and is original and not copied from any source without proper citation. The work has not previously formed the basis of the award of any Degree, Diploma Associateship, Fellowship or similar title or recognition.

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CERTIFICATE

I hereby certify that the Project Dissertation titled "**DESIGN OF 3D PRINTER FOR DENTAL DESIGN AND FABRICATION**" which is submitted by Rishav K. Sharma (2020/SPD/11) to the Department of Electronics and Communication Engineering, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part of full for any Degree or Diploma to this University or elsewhere.

We wish the best for their endeavour.

Place: Delhi

Prof. Rajiv Kapoor
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ABSTRACT

The project aims to work in the medical field, using 3D printing technology of state-of-the-art technology. With the advancement of 3D imaging technology and modeling such as cone beam computed tomography and intra - oral scanning, as well as the longest history of the use of CAD CAM technology in dentistry, technology will become more important. Guidelines for piercing dental implants, portable models of prosthodontics, orthodontics, and surgery, dental and orthopaedic implants, and duplicate and dental implants are all examples of 3D printing applications. The advantages of 3D printing technology include efficient use of materials and the ability to create one complex shape; however, the disadvantages include high cost and processing after extensive processing.

ACKNOWLEDGEMENT

It gives us immense pleasure to express our deepest sense of gratitude and sincere thanks to our highly respected and esteemed guide Prof. Rajiv Kapoor, Associate Professor DoECE Delhi Technological University, Delhi for his valuable guidance, encouragement and help for completing this project. His useful suggestion for this work and cooperative behaviour are sincerely acknowledged. We would also like to express our gratitude to Department of Electronics and Communication Engineering, DTU. We also wish to express our sincere gratitude to our parents whose support has always helped us during this project.

We would also like to express our gratitude to Department of Electronics and Communication Engineering, DTU.

RISHAV K SHARMA
(2k20/SPD/11)

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

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CHAPTER-1
INTRODUCTION

The idea of 3D printing is sweeping the globe[1]. The possibilities are boundless, with promising advancements in the medical and dentistry areas in particular. Traditional dentistry laboratories are not doing so much of a progress if its not 3d printing, the procedure may take loner time with imperfect prints. By 2024, 3D printing might be worth a billion dollars in the dentistry business, which is already worth millions. Although 3D printing is projected to become more common in other areas, better 3D printers and resigns specifically for dentistry are currently being developed.

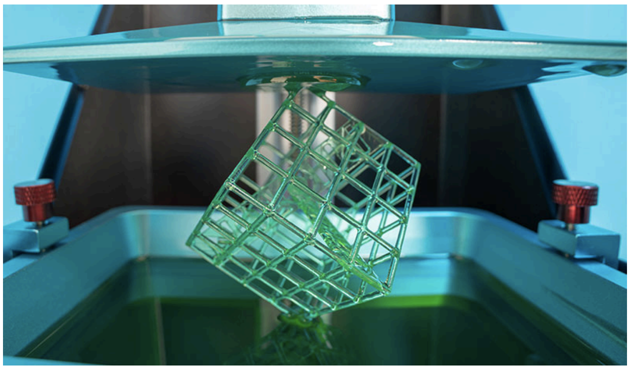

FIG 1.1:- FDM 3D PRINTING

It is also predicted that in the next four years[2], the growth of 3D printing devices in dental labs would quadruple. By 2025, 3D printing tech in dentistry is predicted to meet more than 65% of all manufacturing demands, and maybe even more in some fields like dental modelling.

Here are a few issues to consider while discussing the potential of 3D printing in dentistry[3]:-

1. Repair or filling of a tooth in unhealthy jaw:- The dentist examines the mouth with a scanner. The patient's mouth is 3d modelled and imported on CAD software. A three-dimensional image is created for teeth and gums, which is can be saved as a computer file. Computer-aid design (CAD) software, a dentist can design digitally repair teeth and print a finished product in 3D printer.
2. Orthodontic model:- Prior to the invention of 3D printers, patients were required to bite down on sticky, painful clay that would form into a cast, which would then be used to construct a die for braces to be installed. With 3D printing, this is not the case. The same technology mentioned in the first example may be used by a dentist to make a 3d model

of the teeth, apply design parameters an orthodontic appliance, and get it printed on a 3d printer as final product.

3. Crowns, dentures productions : All types of dental implants may be 3D printed using the same procedure explained above. The only variation is the type of printing substance utilised in the process.
4. Build surgical tools: 3D printers can not only handle implants used by dentist, but they drill guides required for some dental operations can also be 3d printed.

1 3D Printing

3D printing[1][2] is a manufacturing machine which is of additive type. It puts on one layer over the other to develop objects and 3d printed parts. Another term for this is Rapid prototyping. It is a mechanised approach where 3D items supposedly are created swiftly according to the desired size using a 3d printer that reads g code

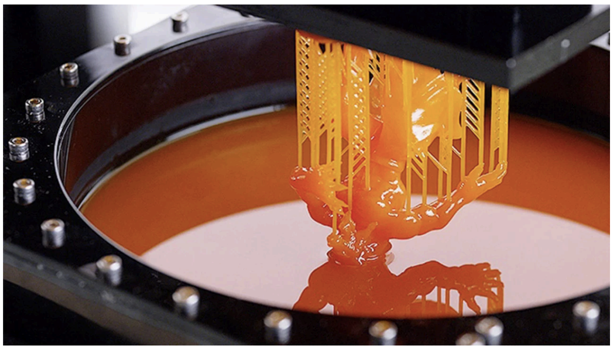

FIG 1.2 :- SLA 3D PRINTING

which is derived from the slicing software.

The subtractive approach, in which material is subtracted by sculpting or drilling from the block, may differ from the additive method.

The primary objective[3] for 3D printer is to maximise resource use, develop dental products lighter and stronger. 3D printing is already is in use widely in a variety of industries, not limiting to aerospace, medical, construction, and the developing prototype of a wide range of industry items.

2 History

As many people believe[4], printing prototypes is not a concept which is new. When the patent for FDM (fused deposition modelling) vanished in 2009, a new area for 3D printing inno ration has opened. Furthermore, as a result of the fact that it became more widespread, many believed that 3d printer is a just another machine for producing not so picture perfect prints. Regardless, the original process which was in the market was SLA, and the first patent was filed in the 1980s then came the FDM printers. From 1980 to the present, here is a timeline of 3D printing advancement.

Three main 3D printing methods were introduced in the 1980s. Dr. Kodana is the name of inventor to assemble a machine which could print by layer-by-layer technique, and he was also the first to develop a machine that could quick prototype objects. He also created a structure for SLA[5][6]. He attempted to polymerize a photosensitive filament with UV light but was unsuccessful. Surprisingly, Dr. Kodana failed to present the entire patent detailsand one year deadline of the application was passed. 3D printing technology is origination back to 1983.

Charles Hull a scientist submitted to patent stereolithography in 1983. In a patent application titled "Contraption for creating 3 dimensional questions via stereolithography" filed on August 8, 1984, Term used the term stereolithography. In addition, he was the primary designer of the SLA-1 (stereolithography) machine in 1987.

FIG 1.3:- EXAMPLE INTERNAL SCANNER

3D System Corporation[7][8] was founded by Charles Hull. Stereolithography, according to Hull, is a unique technology for creating solid things by stacking consecutive layers using a substance which is UV curable on top of each other. A light emission focused is controlled at the centred on the surface filled with a liquid photopolymer in patent's frame, he says. Individual stacking of the model is drawn on the surface by a computer-controlled light beam. The photopolymer polymerizes[9] and solidifies wherever intense light touches the surface. The models are mathematically sliced (converted into layers) using the programme CAD/CAM. The model is then built layer by layer via the method.

In the year 1990, another 3D printing and process innovation emerged. As well as the arrival of new 3D printer and CAD tool makers. 3D Systems sells their first stereolithography (SLA) equipment commercially. Other new procedures were the manufacturing of ballistic particles (BPM), which William Masters authorised, and solid ground treatment (SGC), which Itzchak Pomerantz et al. approved.

Other emerging[10] firms observed between the 1990s and present include Stratasys, EOS, and 3D Systems. In the 1990s, medical research was the first use of a 3D printer, which established the process of pharmaceutical and 3D printing and opened the doors to a wide variety of clients. In 1992, Stratasys secured a patent on fused deposition modelling, which it has utilised to create various 3D printers for both pros and amateurs. This year, 3D Systems developed SLA (Stereolithographic) technology. The first SLA machine builds the object layer by layer, utilising a UV laser hardening photopolymer and a honey-colored liquid. This was the first rapid prototyping technology, and it changed the engineering and design worlds forever.

From 1993 to 1999, the leading players in the 3D printing market, which had grown using various approaches. Sanders prototype (later Solidscape) and Z Corporation were created in 1996, respectively, while Arcam was founded in 1997.

The 3D printing[9][10] business began to display significant diversity at this period, with these two highly specialised regions emphasising each other in a way that is still clearly defined today.

They were extremely high-end 3D printers designed for par manufacture of high-value and intricate components, and they are currently rather costly. This is still rising, but the implications are beginning to show up in manufacturing applications in the automotive, aerospace, medical, and jewellery industries. Some 3D printing systems are on the other end of the spectrum. Manufacturers were developing and advancing "concept modellers," as they were known at the time.These 3D printers continued to focus on the overall development and refinement of these functioning prototyping that were being constructed on a specific basis as these offices and cost-effective systems. On the other hand, these technologies were particularly useful in industrial settings. The 3D printers that are now on the market are at the entry level. Due to advancements in accuracy, speed, and materials, there was a pricing war among 3D printing companies at this period. The first system under $10,000 was released by 3D Systems in 2007, however it never made it to market as expected. This was owing to the market influence of other companies.

3D printing technology advanced during the year 2000, enabling for the construction of lower-cost models with a variety of characteristics. When Clemson University's Thomas Boland patented the use of inkjet printers for cell printing in 2003, it was a revolutionary idea to utilise 3D printers to generate cells. This method was used to modify these spotting systems in order to deposit the cells into highly organised 3D matrices on a substrate. The method of printing biological structures is known as bioprinting. Around the millenium, the first 3D printed kidney became functioning. New printing technologies, such as extrusion bioprinting, have also been investigated and deployed as a production method. As a consequence, organs might be printed via bioprinting.

The RepRap project, a self-replicating 3D printer, was introduced in 2004. The open source nature of the RepRap project led to the widespread adoption of FDM 3D desktop 3D printers, and from there, 3D printers became increasingly popular.

In terms of the year 2020[1][11], Additive manufacturing can currently produce parts for demanding sectors using advanced materials such as extremely resistant and rigid materials or professional flexible polymers. High performance materials are what these materials are called. It's also a way to produce more sustainable production using bio-based components, thanks to a variety of Nylon PA11 materials. BASF and Sculpteo have teamed together to provide you these high-performance materials and to help you take your ideas to the next level.

For the most demanding applications, some of these amazing materials include temperature resistance, chemical resistance, or even heat resistance.

3 Dental Use

Lights or lasers are used in dental[1][13] 3D printers to polymerize a liquid or fuse a powder with the computer-guided accuracy needed to create tiny things with precise detailing. They can create models, components, and even entire restorations from a variety of materials. A 3D printer may boost efficiency in a busy lab or practise, and there are printers suitable for various production

FIG 1.4: HUMAN JAW, 3D PRINTED PROTOTYPE

volumes, lab sizes, and particular activities.

Jaws[14][15] can be created with the help of 3D printers. Jaw bone prototype that can be replanted depending on the condition. Jawbone transplantation was first received by 83-year old British lady.

4 3D scanning

In dental offices[16], 3D dental imaging is gradually becoming the new standard of treatment. Dentists can use 3D dental scanning to digitally rebuild your teeth and cranium in 3D. With 3d scanning Dental professionals now have 3d model which can be used to look over areas where otherwise wasn't possible before. This effective treatment option gives a fresh viewpoint to identify the problem and give treatment options which are targeted and effective.

The most popular applications of 3D dental scanning are for aesthetic and its objectives include restoration and, reconstructive treatment or oral surgery. 3D imaging of patent mouth, lets us plan and customise surgeries including transplantation of bones, implantation of teeth, and creation of root canals. In addition to creating 3D photographs for orthodontic treatment, 3D scanning is frequently employed. There are several benefits to using 3D scanners over traditional dental imaging technologies because of the way they work:

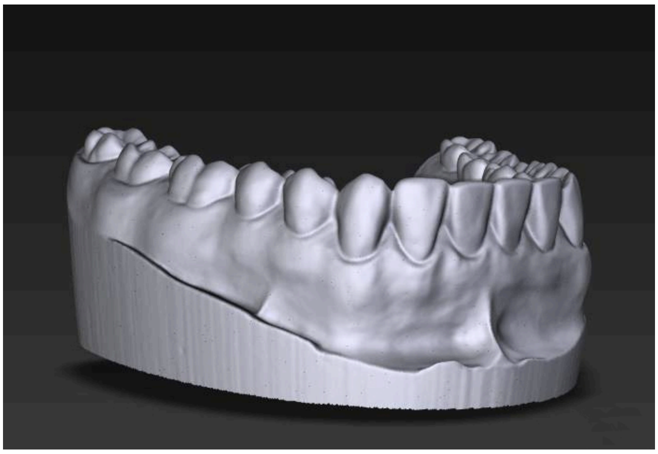

FIG 1.5:-INTERORAL SCANNED 3D MODEL

1. Reduced radiation: Scanners which are used by dentists, limit the amount of radiation a patient is exposed to by scanning quickly and focusing on specific areas. There are three dimensions: Unlike traditional methods, dental scanners produce 3D models, which include far more information than 2D photographs.
2. Exceptional accuracy: When compared to moulds, 3D scans reveal significantly more detail. Conditions such as Pathologies, nerves, infection and few others included musculature can now be tested by the dentists.

Clinicians use many types of 3D dental scanners in their practises.

1. Cone-Beam Computed Tomography (CBCT)

Cone-beam computed tomography (CBCT) scans can be used to scan a series of small X-ray scans on a 360-degree rotating axis. Photo systems usually rotate once in your head while standing or sitting in a chair. The process is very fast, simple and non-invasive. Once taken, the series of images is integrated into a 3D model.

FIG 1.6:- EXAMPLE CBCT SCANNER

2. Intraoral Scanner

Intraoral scanners (IOSs) are portable devices that are used in dentistry to acquire direct optical impressions. They're basically cameras that shine light onto an item, like a dental arch, to create a coordinate map that may be used to create a 3D surface model. IOSs are most usually in the shape of a "wand" that the operator may place directly into a patient's mouth. They're usually made to be simple to use, with light, ergonomic handles and a variety of removable points.

FIG 1.3:- EXAMPLE INTERNAL SCANNERS

5 Modeling

Any case that will involve 3D printed models, like dental clear aligners, splints, Hawley retainers, or occlusal guards, will require digital impressions. There's a simple but necessary step before you start 3D printing: clean up the scanned impression and create a digital model that can be 3D printed. CAD software, such as Meshmixer, may be used to import the scan data. As needed, use the programme to design, create, and clean the model.

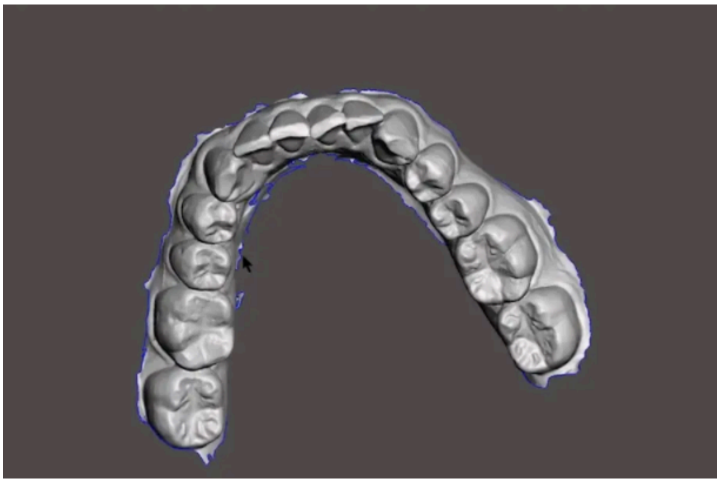

FIG 1.7: RAW 3D SCAN

6 Factors affecting SLA 3D printing

The important[45] aspect of 3d printing specifically SLA 3D printing is very accurate and precise. The resign technology enables us to print very smooth surface which are similar to structure of human parts such as teeth and thus this type of 3d printer ca be used in medical field to print objects. But the print quality gets affected by few thing such as[45][46]:-

- Mechanical control:- The equipment is having moving parts, which directly or indirectly affect the accuracy, the grip on which 3d printer is standing is also a very important factor. Minute vibrations can affect the accuracy and things might not go as planned.
- Material deformation:- Overhang problem occurs when 3d prints are done from resign. Since the material can’t be cured instantly there will be a problem associated with that. The resin will be cured only when treated with UV light, and further steps which include post-tratement baking in the oven. Resuting to this, the SLA deforms and and compromises the actual shape of the design. If a proper support area is not there the accuracy can really get a hit.

- Modeling on a computer:- The CAD modelling software can not be flawless, and there will never be 100% accurate Even if the 3d printer equipment is perfect, control are awesome but still this modelling is a variable in the entire printing process
- Swing:- The importance of printing orientation cannot be overstated. The majority of desktop-grade SLA machines print workpieces in reverse, which means that the majority of them are suspended during the moulding process. Although adding more support material can help to reduce overhang, some material will still hang owing to gravity.
- The thickness of the layers:- It is preferable if the layer thickness is less, as the adjustment is greater when the wall thickness is smaller. After a significant point, however, this is not always the case. According to various research, when the wall thickness is little below 0.1 mm, the precision suffers.
- Temperature and surroundings:- Temperature and humidity fluctuations during industrial 3D printing might impair printing quality. The polymers are extremely weather-sensitive, and bioprinting need the absolute lowest viscosity. The temperature rises as even the viscosity of the resin falls, therefore it's critical to keep it heated (constant temperature). However, if the polymer level is too hot, the workpiece may become excessively loose and weak.

CHAPTER-2
LITERATURE SURVEY

3D Printing Technologies

1. Resign 3D printing

We have multiple resin based technologies such as SLA/DLP/LCD[27][28]

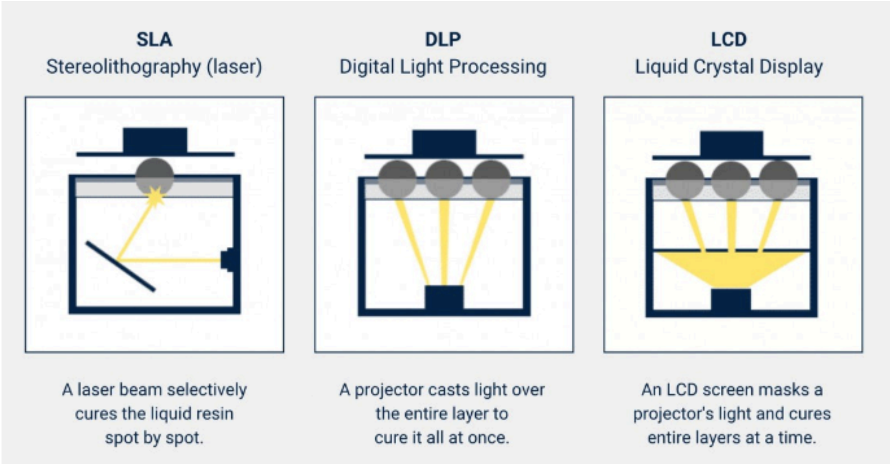

FIG 2.1:- 3D PRINTING TECHNOLOGIES

I. Stereolithography (SLA)

There[27] are various different 3D printers available on the market now for dental purposes. Stereolithography, photopolymer jetting, and digital light processing, which employs light to cure resin, are the main 3D printing methods used.

Stereolithography (SLA) is by far the most frequent and earliest 3D printing method, comprised of a design platform made of photographic resin and an uv laser to fuse the polymer. Photo polymerisation is the process by which a high-powered laser converts the photosensitive liquid resin contained in the laser.

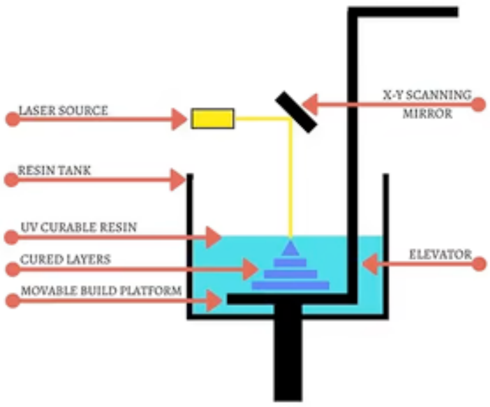

FIG 2.2:- STEREOLITHOGRAPHY APPARATUS

The fundamental technology used in SLA has largely remained that for years. However, recent technological advancements have led to the development of the next wave of 3D printers, that are smaller, less inexpensive, and more effective than that of the prior SLA

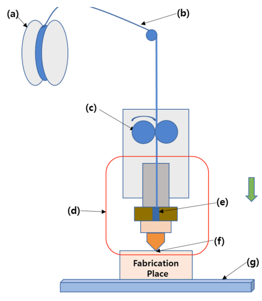

FIG 2.3:-FDM APPARATUS

method. Lower resin quantity and the removal of an oxide inhibition material on the surface of SLA 3D printing processes minimise the total quantity of pores trapped in the finished product, among many other benefits. The SLA method has also been proved to provide great x-y axis manufacturing precision. Using z-direction, the accuracy of the SLA method in 3D printing technology is very important as it depends on many factors. These factors include CAD structure, layer thickness, material structures, data processing, post-processing / cutting processes, and the structure of the visual model, especially in curved or angle areas.

The SLA technique's complete manufacturing process is divided into three steps. Selecting the construction orientation, slicing the STL file, and producing the support structure are all part of the preparation step. The second phase improves the actual construction, while the third phase involves removing the support structure and then post-curing the produced structure. [19] The construction parameters are frequently correlated during these phases, and they have been shown to have a considerable impact on the mechanical characteristics and dimensional correctness of the entire manufactured structure. [20]

Moreover, the build settings used have an effect on the entire building and completion. [21] Alharbi, Osman, and Wismeijer evaluated the effect of build angle and support design (thick versus thin support) on the dimensional correctness of 3D produced filled restorative dentistry.[16].

The outcomes of this original study root - mean - square estimate value and coloring map showed that the design angle and support structural system had a significant impact on the dimensional correctness of 3d printing technology crown repairs. It was determined that the construction angle chosen should provide the crown with the best dimensional correctness and self-supporting geometry. As a result, the lowest possible support surface area is possible, and finishing and polishing time is reduced. [17]

II. DLP Technologies

Other 3D technologies that employ light to cure the resin, in addition to SLA, include digital light processing (DLP) and photopolymer jetting, commonly known as polyjet or inkjet-based method. The utilisation of AM technology to produce a layer-by-layer 3D model based on digital models is embraced by both polyjet or photopolymer jetting and DLP processes . The 3D printing technologies utilised in polyjet and DLP, on the other hand, are not the same as those employed in the SLA approach.

DLP uses a common source of light such as a liquid crystal panel, arc lamp, or projector projector to cure the surface of a vat using photo-polymerising polymer in an exact orientation based on digital design. Both SLA and DLP 3D printing processes require light to cure resin, which is a noteworthy commonality. [5] DLP, on the other hand, uses a projector screen or an arc lamp as the light source, rather than a laser as in the SLA approach. The DLP 3D printer flashes a single picture of each layer in square pixels over the whole platform using a digital projector screen, where the resolution of the DLP 3D printer corresponds to the pixel size. The SLA approach, on the other hand, creates laser spot size pictures with lesser resolution, making DLP a viable alternative to the SLA 3D printing process.

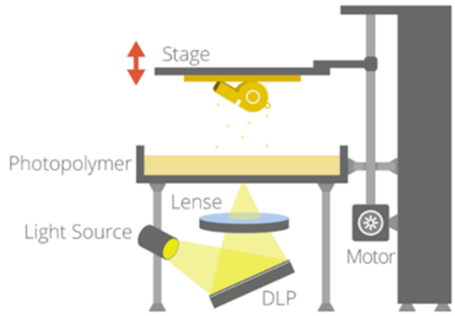

FIG 2.4:- DLP APPARATUS

III. Liquid Crystal Display(LCD)

LCD is the most recent and fashionable technology[27] (LCD). It works in a similar way as DLP in that it cures resin one layer at a time but without the need of mirrors. This is one of the reasons why resin 3D printer prices have fallen to levels comparable to FDM in the non-professional market.

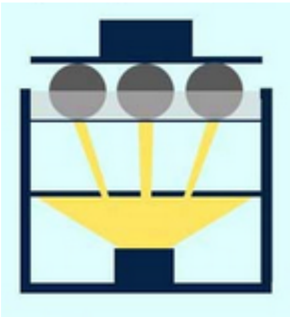

FIG 2.5:- LCD APPARATUS

2. FDM

A nozzle releases tiny beads of thermoplastic material to create a 3D object in fused deposition modelling (FDM). The majority of 3D printers that use the FDM technology are widely used at home, and are hence referred to as "house printers." [21] FDM is a rapid prototyping technology in which a thermostatic material is ejected layer by layer from a temperature-controlled nozzle. In the FDM technology, a thermoplastic filament is fed into a temperature-controlled machine.

The FDM ejection dome is then heated to a free-flowing semi-liquid state. The nozzle's head then guides the material to a precise location where it is solidified layer by layer in under 0.1 seconds. The thing's supporting structures are then artificially produced by cutting them out of the 3D object model design after the expelled material from the nozzle binds to the layer below.

3. 3D printer motion layout

I. Cartesian Configuration

Cartesian 3D printers those with a thermal bed which moves just in the Z axis and are termed after the X, Y, and Z axis three dimensional, which is used to select whether and also how to move in three dimensions. The extrusion is placed on a spindle and may move all along X and Y axes in 4 directions. Printerbot makes it simple. Rather of changing the tip alone in XY space, the printing bed is relocated to change one of the axis. This will be simpler to manage this structure since it is reasonably simple, but at the detriment of printing speed.

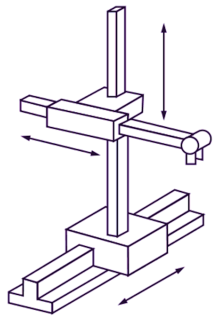

FIG 2.6:- CARTESIAN CONFIGURATION

II. Delta configuration

Delta 3d printers have a circular print bed. The extrusion will be hung from three trapezoid arms from the above, thus the term "Delta." These intelligent robots were built for fast, and they also get a fixed printhead, which could come in handy for the some tasks. The advantages of the Delta arrangement include the fact that when the moving elements are light, they are easier to transport. As a result, printing is faster and more precise.

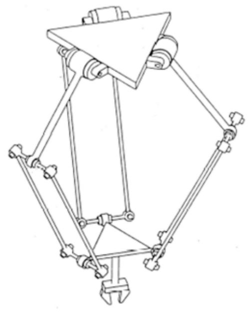

FIG 2.7:- DELTA CONFIGURATION

Because the platform is fixed, delta configurations are considerably superior for producing taller things like vases. They are naturally higher, resulting in a larger construction volume[13]. Because of the way they're built, they're also fairly simple to expand (not in width but certainly in height). Repairs and expenses will be minimized whenever the overall design is less complex and uses fewer parts. Due to the obvious arm construction, that must be considerably taller than the build volume.

III. SCARA configuration

Recommended Compliant Assemblage The SCARA robotic has three components and can operate in one vertically and horizontal plane directions thanks to three servos. The 3d - printed supply assembly is equipped on the robot's back and extended to the robotic arm's end.

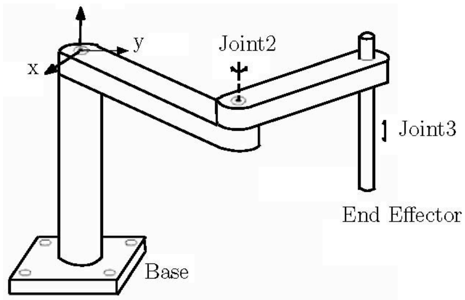

FIG 2.8:- SCARA CONFIGURATION

IV. Polar configuration

This subcategory use a polar coordinate. It's really quite similar to Cartesian arrangement, except that the coordinate sets define points on a round grid rather than a square. As a consequence, you may well have a printer with a revolving bed and a rotating print head. The reality that a pole configuration 3D printer can run on only two stepper is its most significant advantage.

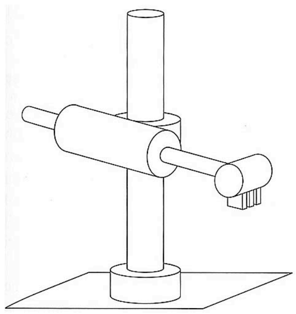

FIG 2.9: POLAR CONFIGURATION

Review on Accuracy

When compared to prostheses built using traditional models, dental prostheses made with 3D printing technology have been found to offer an acceptable level of accuracy and precision. [25] The accuracy of 3-d - printed models in dental casts, according the evidence discussed in the paper, can indeed be beneficial in a variety of dental applications, include diagnostics procedures and surgical procedures. [26] Dietrich, Ender, Baumgartner, and Mehl [27] compared the physical replication of 3-dimensional digital orthodontist resin castings using the SLA and PolyJet systems to determine the correctness (truth and precision) of two distinct fast prototyping processes. PolyJet copies were shown to be more true than SLA models in this investigation, with precise measurements favouring SLA approaches.

However, the study found that both replicas had a maximum dimensional inaccuracy of 127m [27], which was far within the acceptable range of 300m to 500m for orthodontic test accuracy. [28] In comparison to other materials such as Regisil Rigid, Futar Scan, Byte Right, and Aluwax, the study discovered that polyvinyl siloxane materials gave more precise inter-occlusal recordings for effective articulation of digital models.

Kim et al. [29] investigated the precision and accuracy of dental models by comparing the dimensions of 3D printed models (fused filament fabrication (FFF), SLA, DLP, and PolyJet methods) to digital reference models.

The 'trueness' of a model was characterised as the distance between it and a true value, with the least accurate 3D printing model producing replicas within 260 metres of the reference models, which was still within the specified recommendations. According to the findings, there were substantial changes in the precision of all measures, including the accuracy of arch and tooth measurements, when 3D printing methods were used. The results showed that both the PolyJet and DLP procedures had more precision than the FFF and SLA techniques, with the PolyJet approach having the best precision. [29]. DLP and polyjet are both 3D printing technologies that give great precision and surface polish in dentistry, according to several studies. [3,11,30] However, past research has found that polyjet printing generates more accurate models than any other 3D printing method. [27,31,32,33]. Flügge et al. [34] investigated the accuracy of an intraoral digital dental scanner under clinical settings, finding that intraoral factors such saliva and restricted spacing had a substantial impact on accuracy. Brown et al. [4] conducted a research to analyse the accuracy of DLP and polyjet printers from digital intraoral imprints because these are two 3D printing techniques extensively utilised in dentistry. The stone replicas were compared to the 3D printed ones, which were created from digital imprints taken directly from the oral environment. Arch measures comprised arch depth, inter-canine, and inter-molar widths, as well as mesio-distal (crown width) and incisal/occlusal-gingival (crown height) tooth measurements.

The focus of this research was how precise a full digital procedure might be in a clinical setting where tongue, saliva, cheeks, lips, and movements can all be monitored. The findings suggested that both DLP and polyjet printers create clinically acceptable 3D printing models, as stated in a previous study, and that they should be evaluated as effective possibilities for clinical applications in bone function. [4]

Dental 3D printers available in market

3D printing is rapidly transforming the profession of dentistry. Treatments which once took weeks can be finished in just hours cheers to seat manufacturing of dentists models and undergoing surgery, and trying to put native dentists in total control of their physician products – including such night guards, temporary thrones, and false teeth – means fewer consultations, reduced costs, and improve patient care. Let's take a closer look at the expanding variety of choices for digitising your dental office or lab.

Kind	Prints	Printer	Technology	Price Range
Stratasys	Models, surgical guides, night guards, and a framework for a castable partial denture.	J5 DentaJet, Objet30 Dental Prime,	PolyJet, Digital light processing (DLP)	$90,000-$240,000
SprintRay	Crowns, copings, bridges, RPDs, models, surgical guides, personalised night guards	Pro95, Pro55	Digital light processing (DLP)	$ 6,750
Rapid Shape	Models, surgical guides, provisional restorations, removable partials, wax-ups, temporary crowns and bridges, and castable pieces are all examples of dental materials.	D10, D20, D30, D40, D70, D90	Stereolithography (SLA)	$10,000 - $50,000
Zortrax	Crown and bridge patterns, clear aligners, surgical guides, and occlusal splints	Inkspire	Stereolithography (SLA)	$ 1,700

TABLE 2.1:- DENTAL 3D PRINTERS IN MARKET

Biomaterials used in Dental 3D Printing

As mentioned in the preceding section, the profession of dentistry employs a variety of 3D printing techniques. However, the creation of 3D dental materials has received a lot of attention in the literature, in addition to these approaches. Hydrogels, metals, ceramics, resins, and thermoplastics are just a few of the biomaterials available for 3D printing.

Table 2 demonstrates the compatibility of dental materials and the precision with which they may be replicated using 3D printing.

Technology used	Compatible Dental Materials	Approximate Accuracy *
FDM	Acrylonitrile butadiene styrene (ABS), Polyesters, Polypropylene or Polycarbonate	35 to 40 µm
SLA	Ceramics, Acrylate photopolymers or Plastic	50 to 55 µm

TABLE 2.2:- TYPES OF 3D PRINTING TECH

A. Hydrogels

Hydrogels are long been thought one of the most effective components. Hydrogels typically composed of pores that are connected by hydrophilic polymers which retain water [28-30]. This is beneficial because it mimics the properties of the cell membrane in nature (ECM). Hydrogels have a wide variety of biological, chemical, mechanical, and viscoelastic aspects, as well as elasticity [31]. The imprinting of the polymeric hydrogel is governed by its viscous. To remove the pipes and build and stabilise the construction layers, it has to be both fluid and viscous. Alginate hydrogels, for example, are connected to the calcium ions before they are released into the nozzle to measure the viscosity of the polymer hydrogel in the ideal state. The one and only type of hydrogel available now is photocrosslinkable gases, that can be created or destroyed by ultraviolet (UV) radiation. In addition to the natural abundance, synthetic hydrogels like as polyacrylamide (PAM), poly (ethylene glycol) (PEG), poly (2-hydroxyethyl methacrylate) (PHEMA), and poly (vinyl alcohol) (PVA) are employed in 3D printing. Because of their controllable geometries and good mechanical characteristics, hydrogels are desirable.

B. Polymers and Thermoplastic Materials

Polymer-based 3D printing is by far the most widely employed of the various available materials for increased supply. Todays modern 3d printing technologies can print a wide range of polymer composites for dental work, restorative materials, and other 3D tissue constructions [33]. Photopolymerization is among the polymeric dyeing techniques used in 3D dental imprints. [33] Polymers which can be utilised in the oral cavity include polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polypropylene (PP), and polyethylene (PE). PLA was deemed preferable than ABS inside the oral cavity due to its superior impact durability and non-toxic characteristics [26,35]. The thermoplastic filament materials PEEK (polyether ether ketone) and PMMA (polymethylmethacrylate) with high melting point have lately been utilized in 3D dental printing [36]. Generally, developments in device technology for 3D printing materials so at dentistry are now being supported by the development of visible polymer qualities, be it in the form of resins, powders, or filaments.

C. Ceramics

Ceramic materials are a popular 3D printing material, specifically in the field of prosthetic dentistry. SLA and SLS [25,26,37,38], where customized ceramic powder or pre-sintered ceramics are utilized to achieve strong bonding, often use ceramics.

In experiments, ceramics comprising calcium and phosphate mineral phases, such as hydroxyapatite and tricalcium phosphate, have been shown to create a biocompatible microenvironment. Due to the difficulties associated with post-processing to high density, ceramic powder can only form porous structures using SLS. Furthermore, additive manufacturing processes have their own set of restrictions, such as anisotropic shrinkage when sintering ceramics and stair-step effects on surfaces when fabricating.

D. Metals

Metal is yet another prominent material in dental clinics. Its popularity has also been seen in world of 3D printing, especially in the employment of SLS. The dentist examined at metal objects made of titanium, cobalt-chromium (CoCr), and nickel alloys. Nickel alloy, especially nickel-chrome (NiCr), that's no longer considered a great dental implantation by researchers due to the risk of metal allergies in the mouth. Producing metal dental implants using SLS, like pottery, produced hollow objects which necessitated the use of a wide range of laser intensity and range. SLS processes have advanced further as a result of the recent research, such as the use of vacuum during metallic dental prosthesis [26,42-44]. 3D-printed dental implants can be made of metals like titanium and CoCr.

3d printing techniques and materials can be utilized in healthcare environments. Ceramics like zirconia and metal alloys like CoCr are not suited for SLA or SLM to make 3D dental implants. Further study is required to better understand how these 3D printing techniques and materials are being used in medical applications.

CHAPTER-3
METHODOLOGY

1. Flow Diagram

Although the design and fabrication method for 3d dental design different from traditional denture fabrication, the bird eye view is similar. This flow diagram explains how to take the design from scanned patient model to fully 3D printed complete denture.

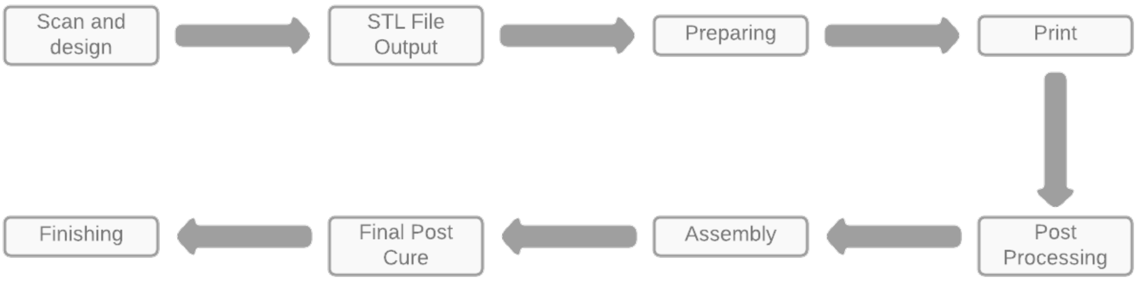

FIG 3.1:- FLOW DIAGRAM OF DENTURE FABRICATION

The various components comes under flow diagram are:-

1. Scan and Design

In order to construct the removable prosthesis, digitised model is required or imprint of the

FIG 3.2:- 3D SCANNER

patient's oral anatomy. The best approach for producing a digital file for completely edentulous is to scan the clearly developed, poured model, and wax rim with a desktop laboratory scanner. Using the scanner that gives out fine model accuracy is important.

The digital scan of the denture is used as import file for Design software.

2. STL File Output

The digital denture method requires denture teeth, also known as card libraries. The compatibility of libraries varies depending on the software.For instance, certain "open" libraries contain output restrictions. Splinted denture teeth are created by certain libraries, but not individually.

FIG 3.3:- SCANNED 3D MODEL OF TEETH

3. Preparing

When you've exported the STL files from of the denture design software, import them into slicer, the application that combines files for printing on the 3D printer.

Choose the printing material and set the Orientation. Positioning of teeth should be at 10 to 25 degrees. On the places where the teeth contact the base, avoid support touchpoint. Also add support to the denture.

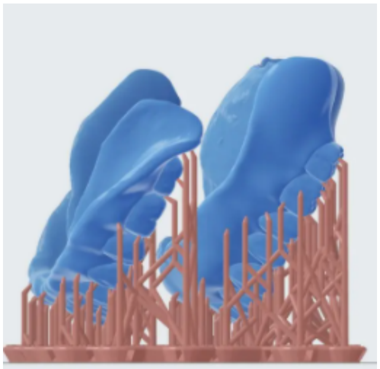

FIG 3.4:- ORIENTATION SUPPORT

4. Print

To setup the 3D printer, add a polymer tank, polymer cartridge, and build platform. Before using the resin cartridge, give it a good shake. Send the work to the printer and the printing will begin.

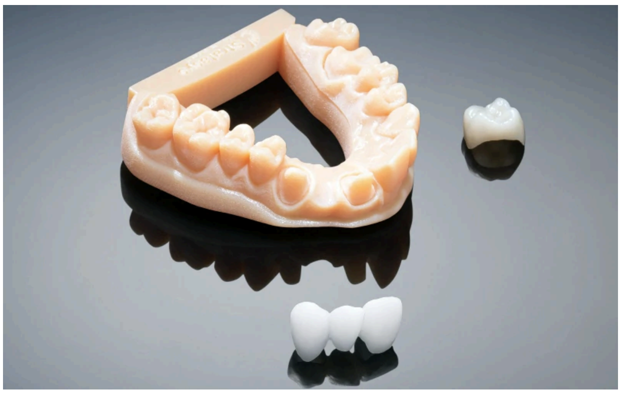

FIG 3.5: 3D PRINTED TEETH

5. Post Processing, Assembly, Final Post-cure, Finishing

Release the printed dentures base or dentures from the build platform with the component removal tool, or wash immediately on the build plate using Forming Wash. Soak the component in 96 percent or higher isopropyl alcohol (IPA) for 10 minutes to dissolve any uncured or surplus resin. Once the pieces have been thoroughly cleaned, detach the raft and support from the base and teeth. Wash the parts in IPA for yet another five minutes in Form Wash after detaching the support and raft.

Put the dentures into the denture base to evaluate the fit. Just use hand tool to trim the teeth and base as needed if anything is preventing seating. The denture is now back for the final step in the post-cure process.

Fill a glass bottle halfway with glycerin. Preheat the glycerin to 80°C in Form Cure. With heat resistant silicone tongs, immerse the prefabricated denture in the glycerin, keeping the container in Form Cure. Cure at 80°C for 30 minutes.

Once post-curing is complete, gently remove the denture from the glycerin using silicone tongs. Wash the final denture with room temp water and heat clean it to sterilise it.

CHAPTER-4
DESIGN AND FABRICATION

1. Conceptual Design

In the initial stage of CAD design[47][48], we were using dual timing belt system to generate motion along z-axis,

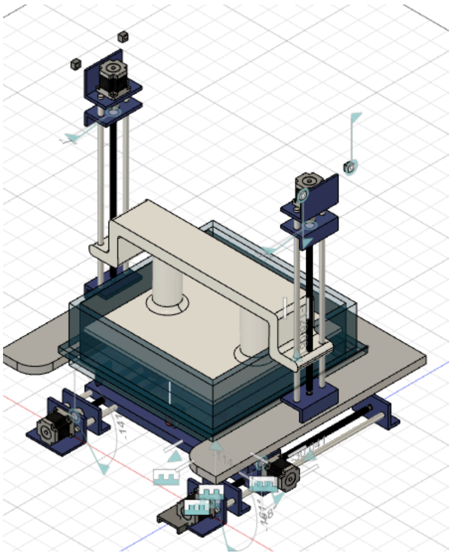

FIG 4.1: DESIGN WITH DUAL Z AXIS (TIMING BELT)[OLDER VERSION]

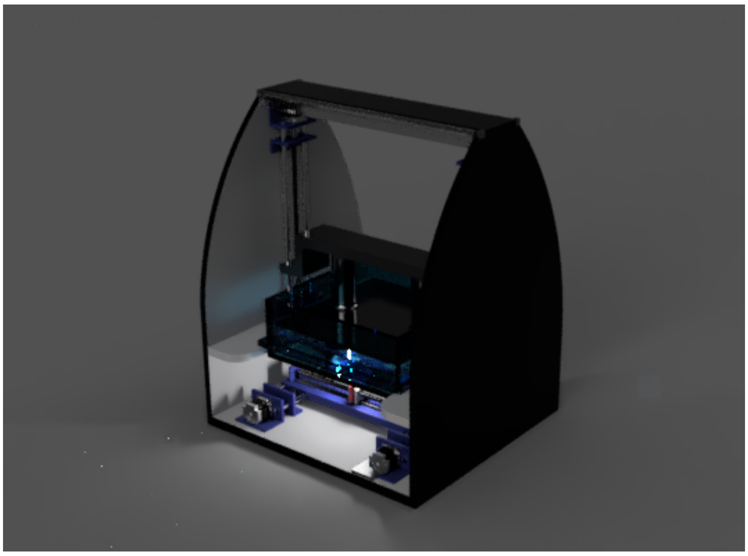

FIG 4.2:- RENDERED 3D MODEL WITH DUAL Z-AXIS (TIMING BELT) [OLDER VERSION]

Timing belts[49] are a good solution for linear motion, but are not a good option where accuracy is required. Design having timing belts are prone to elastic degradations/variations which makes such 3d printer not useable. On the other hand, using linear railing which are a bit expensive than timing belts but price compensates the accuracy, strength the bring to the 3d model. Having linear motion railing[49][50] is better solution than having timing belts, but still have issues that comes with single axis linear motion guides which

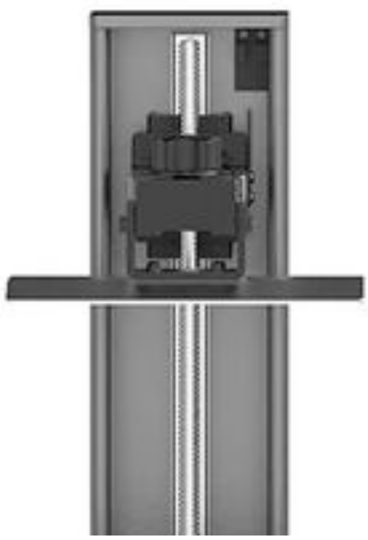

FIG 4.3:- SINGLE AXIS RAILING

includes instability and jerking for larger prints.

After reviewing research papers and books[49][50][51][52], we altered the design to include a single linear axis railing which has benefits related to less jitter, vibrations and timing issues.

Later we made our design more Stable Movement on the Z-axis[53][54][55] with Dual Linear Rails. The T-shape screw rod and the Z-axis with dual linear rails ensure accurate and steady movement.

There is no printed layer deviation, and the layer texture is substantially reduced. Even the most complex models will print flawlessly.

FIG 4.4:- REINFORCED Z-AXIS DESIGN

2. Procedure selection

As 3D printing evolves[56], the list of technologies and techniques for 3D printing continues to grow. The 3D printing business is constantly improving its hardware, materials, and tactics for producing protests and parts. Choosing the appropriate 3D printing process and material is critical, depending on a variety of aspects such as budget, design, and capacity.

LCD technology is clean, simple to be using, and friendly to the environment. Complex forms and complex parts can be printed. LCD-based tech has been at the forefront of the market because it is primarily utilised by people. The LCD is a much more accurate method than some other 3d printing techniques.

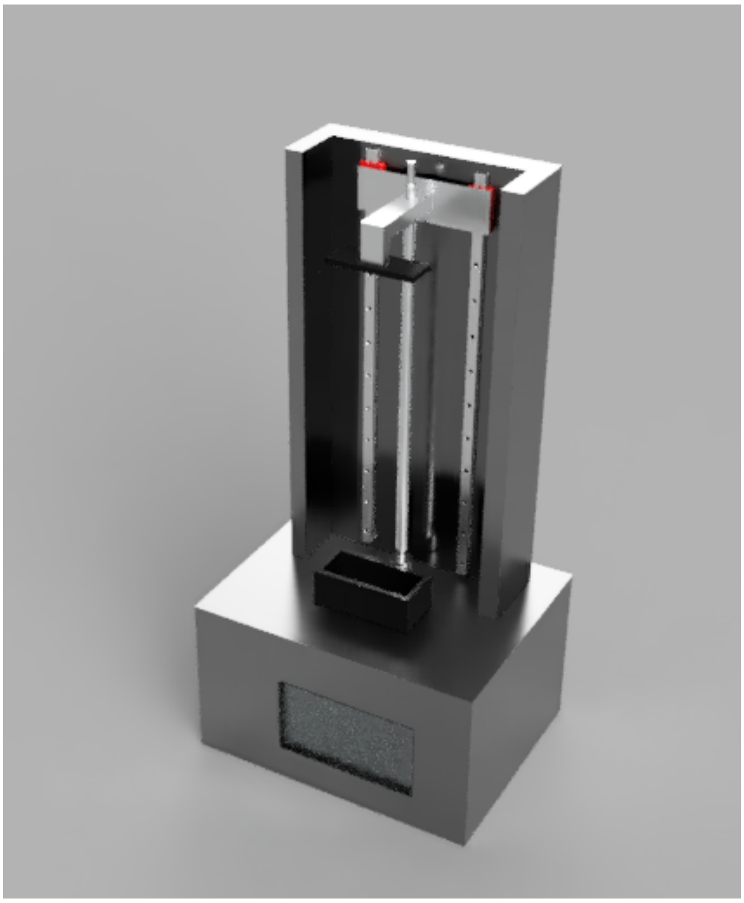

FIG 4.5: CAD MODEL, P1

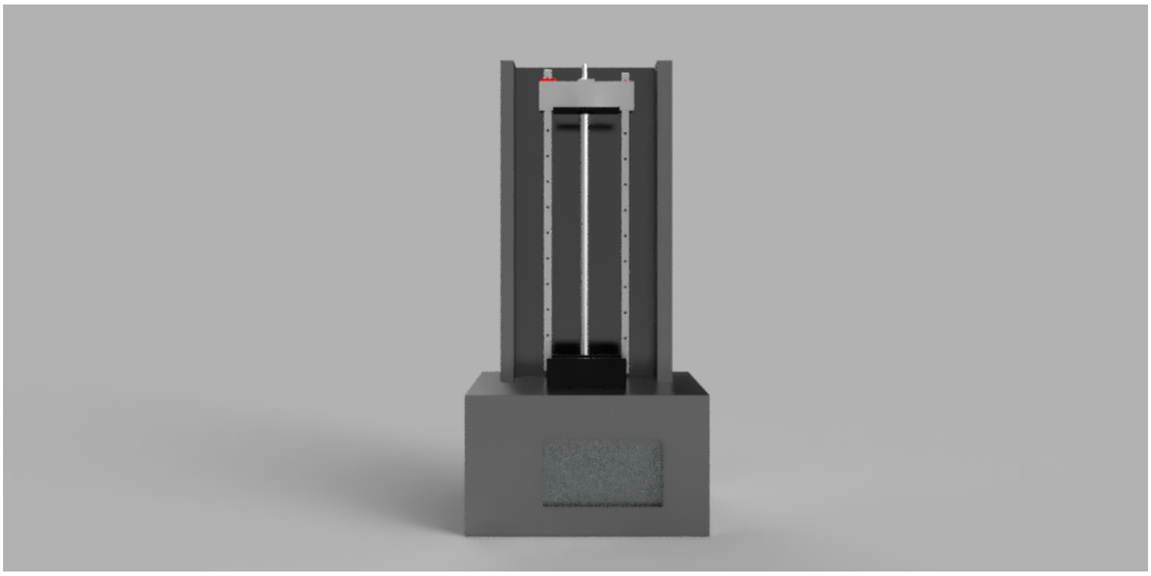

FIG 4.6:- CAD MODEL DESIGN, P3

The LCD begins with such a product-specific STL file (stereolithography file format), which will then be cut and set in a scientific way. Support structures can be built if needed. The machine may distribute a variety of items to achieve different goals. The model or part is made by dipping the plate in the eraser, which hardens immediately after leaving the liquid.

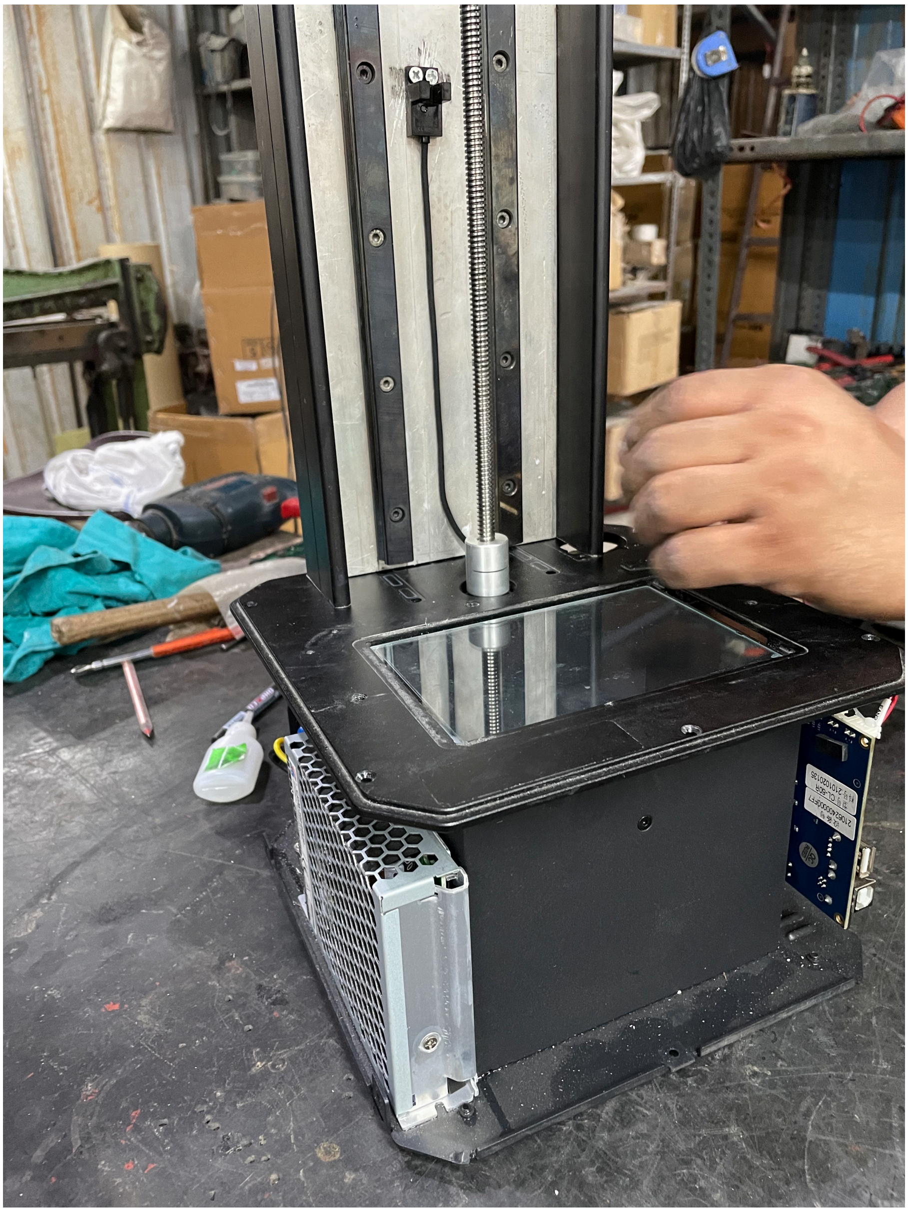

FIG 4.7: HARDWARE IMPLEMENTED DUAL AXIS REINFORCED RAILING[FINAL DESIGN]

3. Mechanism Selection

SCRA, Cartesian, Polar, Delta[52][53][54], as well as other methods are currently being used in the development of SLA 3D Printers. Whenever the bed is straight in the Z pivot, we've selected the Polar growth configuration. The development of the Z-hub in such a 3D printer is extremely precise and requires very low values, however the bed has to be lighter to maintain accuracy, this make assembling a fully structured frame for controlling the bed quite difficult.

The 3D printer line movement system is one of the most important ways to build a 3D printer. The 3D printer line movement moves the built-in x-axis, y-axis, and z-axis.

The built-in x-axis, y-axis, and z-axis are all moved by the 3D printer line movement.3D printers feature two basic components: an engine that converts electrical energy to rotating motion and a system that converts a rotating motor vehicle into the a sequence drive. Stepper motors are used to operate line motion systems in all 3D printers on the market today.

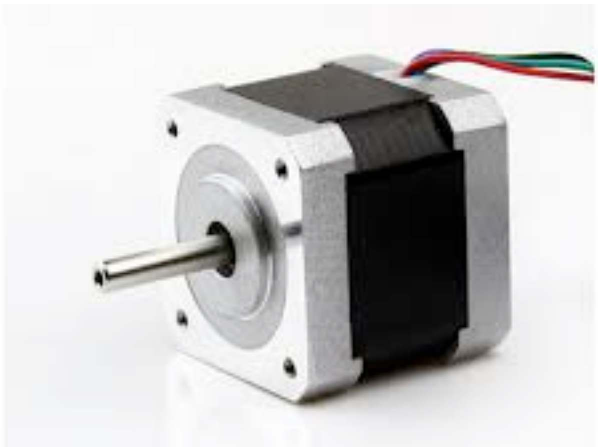

FIG 4.8:- STEPPER MOTOR

There are many ways to make smooth line movements.

3.1. Screws with lead

Lead screw systems are indeed a simple way to transfer a stepper motor's rotational movement into direct movement of a 3D printer's construction and/or extruder. The movement system of the lead screw line consists of a motor with stairs around the rod rod and mounting nuts up and down the cable rod as it rotates.

There are several drawbacks to all lead screws. To begin, they all need to be lubricated on a regular basis to prevent wear and improve performance. Second, lead screws in general wear out faster than other linear motion systems. Third, lead screws are noisy due to the metal-on-metal contact between the lead screw and the nut. Finally, backlash is a problem with lead screws. Because of this, lead screws are rarely utilised for the z-axes. These axes change directions frequently, and because most lead screws have backlash, the positional accuracy suffers each time the screw changes direction. For a long print, this can become a major issue.

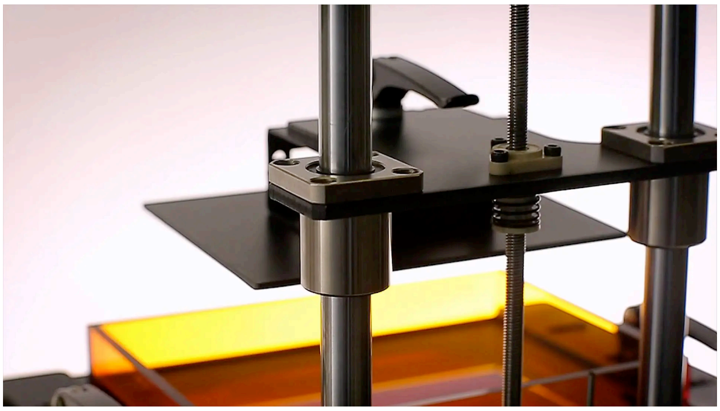

FIG 4.9:- A NUT PROVIDES MOTION TO THE LEAD SCREW IN THE MIDDLE.

3.2. Timing Belts

Most 3D printers use belt drive on the x- and y-axes[51][52][53]. A timepiece with teeth, a pulley with teeth attached to the engine, and a cart attached to the belt make up the driving belt. When the engine rotates, the pulley rotates again. When the motor turns the pulley, the teeth in the pulley meet with the timing belt teeth, pulling the timing belt where it needs to move. The cart is usually attached to the belt and pulled back and forth with it.

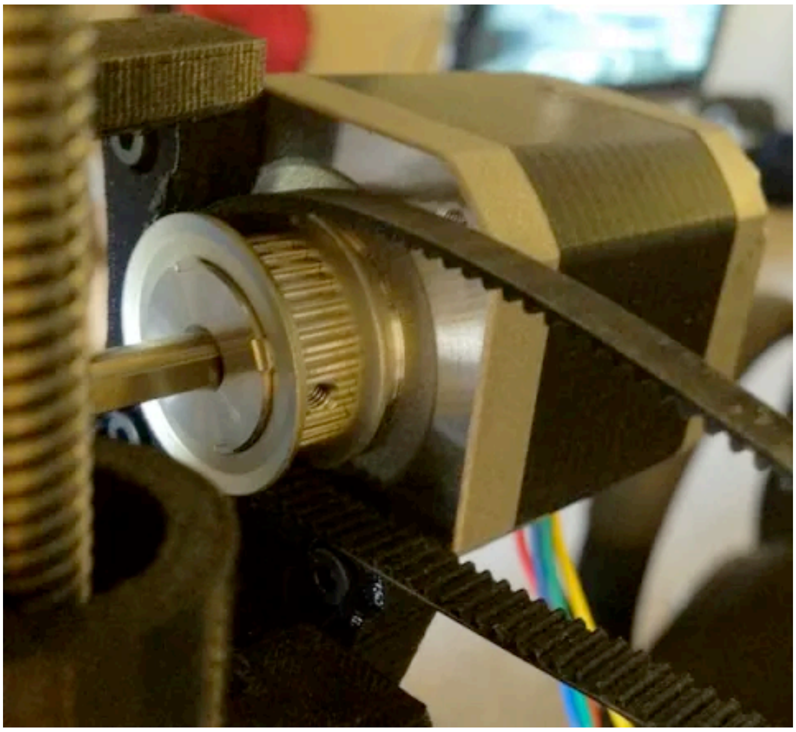

FIG 4.10:- THE MOTOR POWERS A PULLEY THAT CONNECTS TO THE TIMING BELT.

One of the drawbacks of belt-drive 3D printers is that their belts are prone to stretching, which can cause production issues.

Lead screw printers, on the other hand, are readily misaligned, and backlash can build up over time. They can also soon wear off, resulting in further costs for you.

3.3. Linear guides

Linear motion guides[51][52][53], also known as linear slides, are common motion components used to achieve smooth sliding movements. 3D printers, CNC mills, waterjet cutters, and other machines use them.

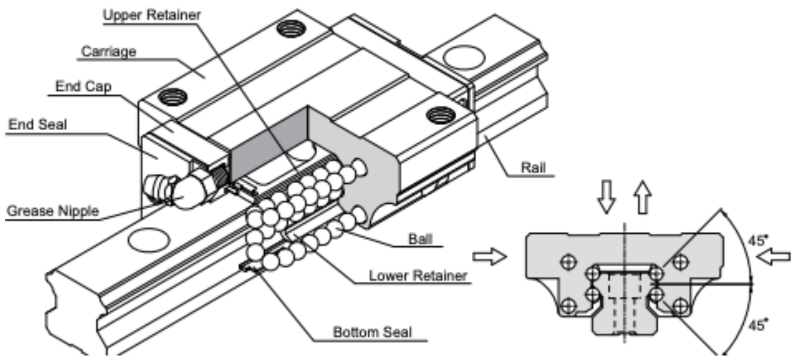

FIG 4.11:- COMPACT TYPE, MSG TYPE

Ball trains have a 45 ° contact angle, which allows them to maintain equal weight in radials, reversed radial, and side-by-side directions. As a result, it can be included in any shape. In addition, the MSB series may produce well-balanced pre-loads to increase the four-dimensional strength while maintaining low friction resistance. This fits well with movements that require great precision and durability.

Advantages of using MSB15S dual railing:-

- Compact, Equivalent Four-way Load
- Smooth Motion with minimal Noise
- Self Alignment Capability
- Interchangeability

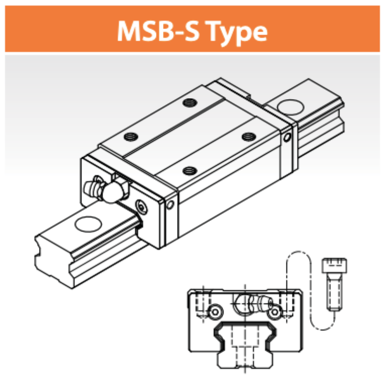

FIG 4.12:- MSB-S TYPE

The oil is equally distributed in each circulation loop thanks to the unique design of the lubrication route. As a result, optimal lubrication may be accomplished in any installation direction, which improves operating precision, service life, and dependability.

A linear rail is a strong steel rail that a carriage moves along. Recirculating ball bearings are often used in carriages to provide contact points between the carriage and the rail. As the balls roll between the surfaces, this allows for a smooth sliding motion. The shaft's form allows the carriage to stay locked on with precise tolerances, limiting motion to linear directions only.

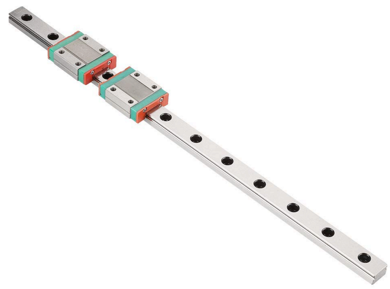

FIG 4.13 :- LINEAR GUIDES

Linear rail 3D printers claim to attain greater motion by utilising the multiple advantages of these linear rails.

4. Detailed design

4.1. Z – axis Movement

The CAD model provided[56][58][59] for the direct movement method is shown in Figure.As illustrated in the diagram, the lead screws, shaft coupler, flange nut, and print bed are all aligned. The rotary motor movement is transferred to the bed in response to

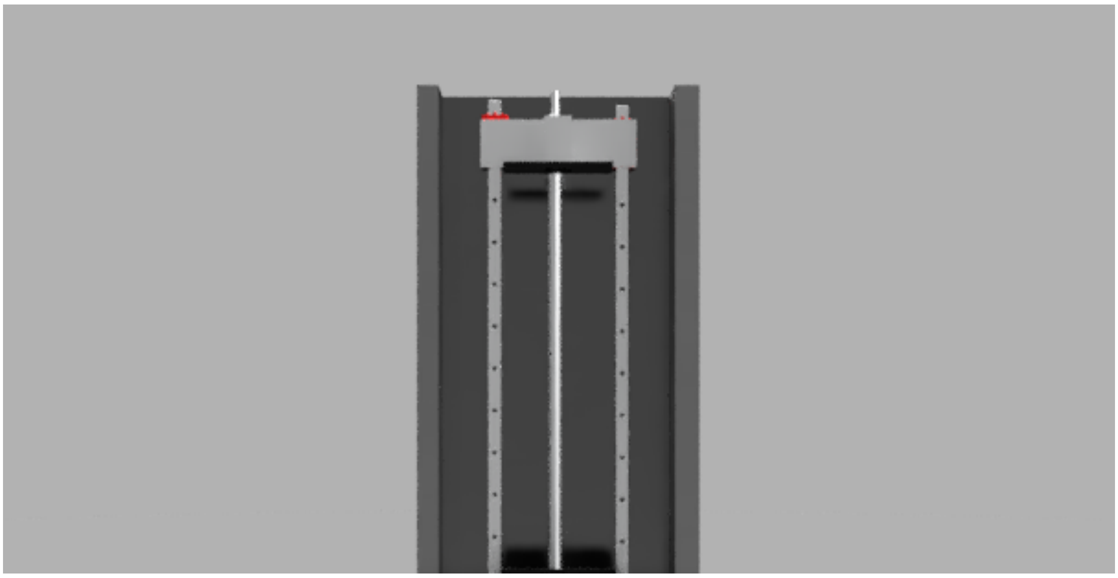

FIG 4.14:- REINFORCED Z-AXIS

leadcrews, which are attached to the bed through a mechanism, as indicated. The torque produced by the motor is transferred to the lead screws via the shaft coupler and flange nut. The shaft coupler rotates the lead screws in the same direction as the motor when it rotates in one orientation, such as clockwise. Threaded couplers link the bed to the lead screws, which

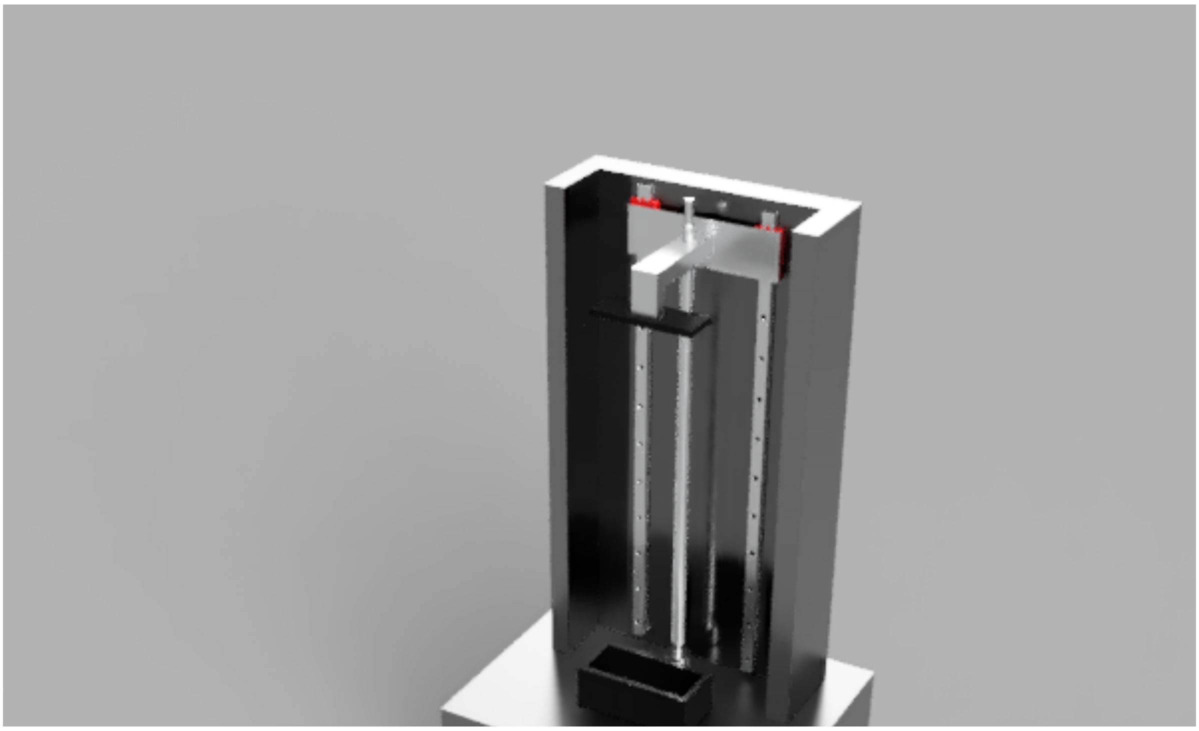

FIG 4.15 :- REINFORCED Z-AXIS

allows the bed to move vertically as the lead screw revolves. Dual linear motion rails strength the structure and gives a smooth z - motion. Dual z-axis reduces reduces friction, support larger loads, guide moving parts.

To develop this vertical movement mechanism[57][58], we must first determine the 3D printer's print dimension of 127 x 80 x 160 mm. The height of the lead screw and the area of the bed are estimated based on the volume. Figure depicts the print bed, which is made out of a metal that is attached to dual z- axis through a aluminium sheet.

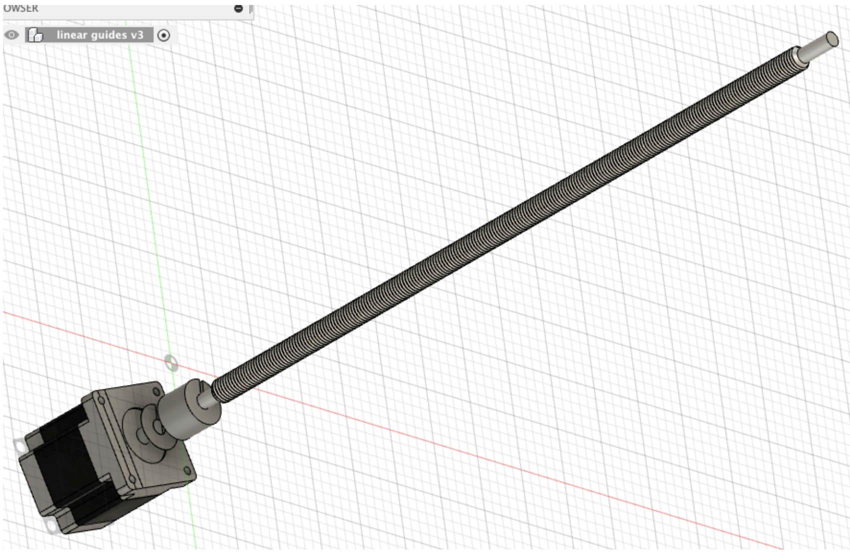

FIG 4.16:- MECHANISM FOR Z – AXIS MOVEMENT (VERTICAL DIRECTION)

CHAPTER-5
ELECTRONICS

The electronics board regulates them because they are the most important part of the printing. Beginners, developers, and manufacturers would appreciate how easy it is to integrate and use the electronic system. The power cables of parallel connection can be connected using the many quick connectors.

The electronic includes the following components:

- Controller Board
- Stepper Motor
- Light Source Generation
- End Stops
- Power Supply

CONTROLLER BOARD

Motherboards[59][60][61] are the brains of 3D printer, they handle power determines how nice or accurate your finished prints will be. Printer control boards continue to change to include additional functions that enable easy adjustment using microstepping. For complex calculations, Even more powerful CPUs and boards with their own operating system are available. There are also sophisticated processors with sophisticated calculations, as well as devices that use their own operating system.Controller board is divided into sub systems such as:-

- Light Board
- Cooling Fan Port
- Exhaust Fan Port
- DC Power Input Port
- Light Board Power Supply Port
- Z-Axis Motor Drive Port
- Z-Axis Limit Switch
- Print Screen Port
- RGB Screen Port

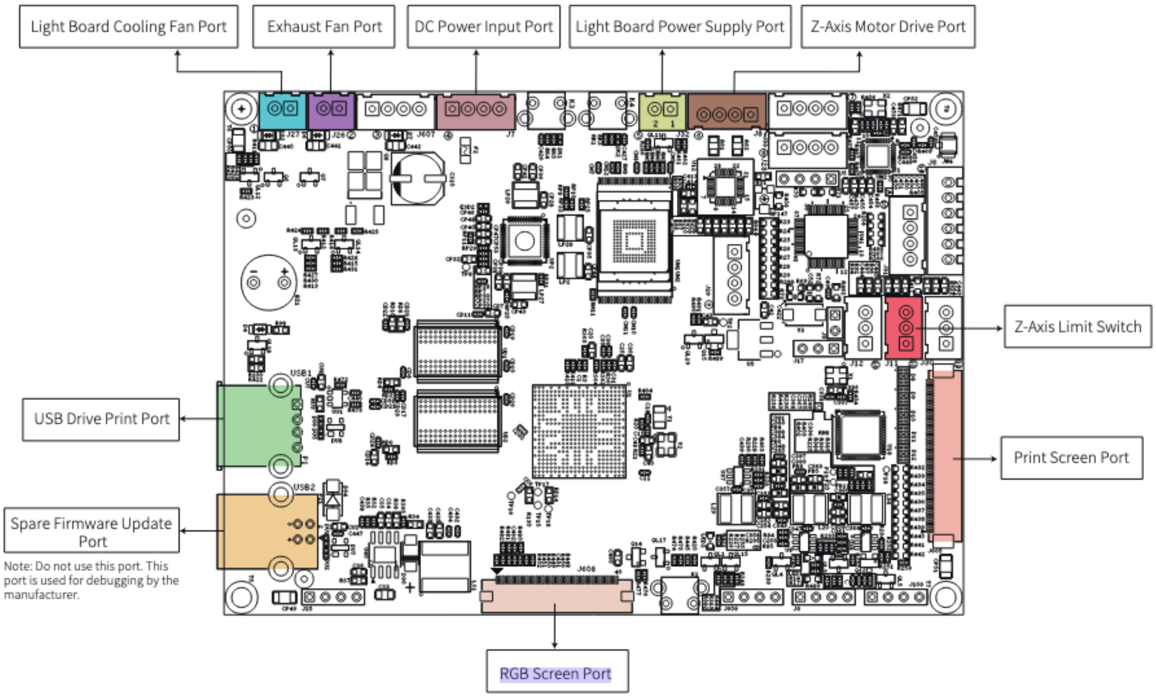

FIG 5.1:- CIRCUIT DIAGRAM OF CONTROLLER BOARD

The controller board is consisting of 64-bit, 4 core CPU/GPU, based on ARM cortex-M4 cores. It includes a attachment for 5 inch touch screen, on a linux kernel based OS with OTA firmware support.

Stepper Motors

A typical motor, whether electric or not, revolves in a periodic, regular, circular motion. Stepper motors differ from regular electric motors in that they selectively spin a set percentage of a revolution, termed steps, and can start and stop at whim, allowing devices like 3D printers to accomplish exact motions. A dismantled stepper motor may be seen in the image above. When electricity passes through the wires, the coils within are activated, causing the remainder of the components to move.

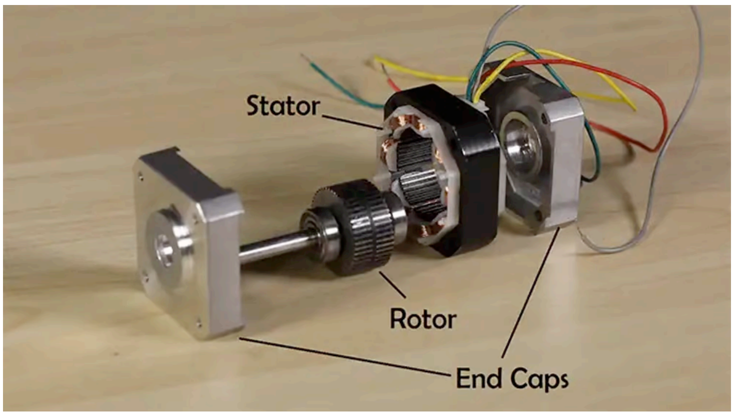

FIG 5.2:- UNASSEMBLED STEPPER MOTOR

These coils are controlled by electrical pulses that may be regulated extremely accurately, giving the machine its well-known accuracy.

The selection of a stepper motor is based on characteristics such as:-

- Step Angle

There is a step angle on a stepper motor. The number of steps per rotation is calculated by adding all 3600 circles separated by the progression edge. For example, a typical advance size rating is 1.80 for each full advance, corresponding to 200 steps each revolution.

The majority of Mendel stepper motors feature a 1.8 degree step angle. It is sometimes feasible to utilise a motor with bigger advance points, but they must be cut down to lessen the edge moved every step, which may result in a slower peak speed.

- Micro-Stepping

A stepper motor's step size remains constant. To improve the set of activities on a tiny scale, a sine/cosine waveform is communicated to the curls within the stepper motor. Miniaturized scale measurement allows stepper engines to operate more smoothly and accurately in most situations. Navigation with small scales between the transmission areas is achieved by lowering the torque, but there is a very small tendency for mechanical movement in the forward positions and can be driven by very high waves. If the engine is close to mechanical blockage and has severe attrition or flow, small size measures would not give you lots greater precision than slow operation.

- Bipolar

The bipolar interior of the automobile is handled by a separate stepper driver circuitry for each kind. Bipolar steppers are the most robust available. To find it, collect the clues; there must be four or eight. Stepping the motor around can be done by opening the coils and adjusting the current strength flowing between them. Since this requires more complex electronics than a unipolar motor, we use a separate chipset to handle everything.

- Unipolar

Unipolar motors are made up of two coils, each with a central tap. Because they have 5, 6, or even 8 leads, they are easily identifiable. You can use 6 or 8 lead monopolar motors as bipolar motors by disregarding the centre tap wires. Rewiring a 5-lead motor to a 4-lead version necessitates at the very least opening the motor because both middle taps are connected.The primary advantage of unipolar engines is that they may be stopped without reversing the current direction in any coil, making them easier to use.

- Holding Torque

Comparable DC servo engines or DC-powered actuators give greater torque and grip power than stepper engines. Positional control gives it an advantage over all these engines.

- Size

The NEMA standard, that specifies its shaft width and darts up the example, is often used to represent the physical dimensions of stepper motors. Stepper motors are evaluated by their depth in millimetres in additional to the NEMA estimate rating. A motor's power is proportional to its body dimensions on a regular basis.

- Shaft

Any object that fits on a stepper drive shaft should have a diameter of around 5 mm. There is a varied size on the shaft; you will need to account for this in the (plastic) pieces you get. We will use a permanent magnet type NEMA 17 stepper motor based on all of the above variables.

- Types of Stepper Motor

- NEMA 11
- NEMA 14
- NEMA 17
- NEMA 23

A. NEMA 11

This bipolar hybrid stepping motor has 200 steps per turn and a 1.8-degree angle. Each cycle draws 670mA at 3.5V, generating a gripping torque of 600 gcm. These motors will be linked to the bear path by four coloured cords: black and green on one coil, red and blue on the other. It also can be regulated with a pair of suitable H bridges.

B. NEMA 14

A explicitly describing on this 200-step/revolution hybrid bipolar stepping motor is 1.8 degrees. Each cycle draws 500mA at 10V, resulting in a 1 kg-cm maintaining torque. These motors are made up of four color-coded wires with bare leads: black and green for one coil, red and blue for the other. It can be regulated using a pair of suitable H bridges.

C. NEMA 17

A 1.7x1.7 inch faceplate is standard on the NEMA 17 stepper engine. The NEMA 14 is also larger and heavier than some other types, like the NEMA 14, but this means it has much more space for more torque. Its size does not correspond to its strength. This bipolar-coded step provides 1.8 degrees for each advancement with smooth motion and strong grip torque. The current gen size has been determined to be 350mA, allowing it to run smoothly with Adafruit Arduino engine protection and a detachable connector or battery that produces decay.

D. NEMA 23

In the this high torque hybrid stepping motor, the step angle is 1.8 degrees. Each phase draws 1A at 5.7V, giving in a torque of 4 kg-cm. The motor has a six-color wiring that cuts off the blank track and may be controlled either by unipolar or bipolar steppers. For use with a unipolar stepper motor, it utilizes all six tracks. If using a bipolar stepper motor, the middle yellow and white pump wires can be left unconnected.

CONCLUSION We are using the TABLE specs for stepper motors for dental 3D to suit our design requirements.

Dimensions	42 x 42 x 48 mm
Shaft Length	18 mm
Step Angle	1.8 degree
Maximum Voltage Input	24 V DC
Rated Current	1 A
Holding Torque	6.12kg.cm Typ.
Stepper Type	NEMA17
Shaft Diameter	5 mm

Table 5.1:- Stepper Motor Specifications [Creality 42-48]

End Stops

Z-Cartesian axes require datum to direct their movement. Each axis should be supported until the data point at the beginning of its construction. Switches also store equipment that exceeds the intended distance and causes damage.

FIG 5.3:- IR BASED LIMIT SWITCH

Light Source Generation

The reflection and refraction concepts are used in the LCD integrated light source. The entire screen can be illuminated by a single light source, ensuring that the intensity of the light source is distributed evenly across the screen; the uniformity of the light source is over 95%, ensuring that the accuracy at the same layer is identical; the function is unaffected even if one of the lamps fails, ensuring the accuracy of all axes at the same level; and it increased the success rate.

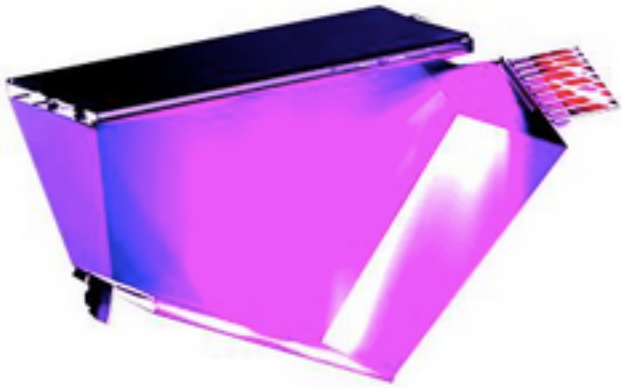

FIG 5.4:- LCD INTEGRAL LIGHT SOURCE

Light source wattage	120 W
Illumination uniformity	80%
No. Of Light Sources	6
Light source output	3800uw/cm2
Wavelength	405 nm

TABLE 5.2:- LIGHT SOURCE SPECIFICATIONS

Apart from that we are using Monochrome technology, as compared to cooler one. Monochrome display have added benefits such as shorter layer exposure times and speedier prints, as well as a longer LCD panel lifespan.

FIG 5.5:- MONOCHROME DISPLAY

Dimensions	221x221x404mm
Weight	7.1 Kg
Type	Monochrome
Resolution	2560*1620 pixels
Print Granularity	50 micron

TABLE 5.3:- LCD SCREEN SPECIFICATIONS

Power Supply

Depending[57][58][59] on the light source and lcd screen, 100W power supply is employed for smooth functioning and is recommended. Complicated circuits convert current main AC into DC voltages required by the Steppers and Electronics circuit inside the power supply switching power. The switched mode power supply's key benefit is that it is exceptionally efficient in converting power.

CHAPTER-6
FIRMWARE AND SOFTWARE

Firmware[53][54][55] is software that really is continuously stored inside a read-only memory (ROM) or a fixed memory system that enables a device to also be managed by hardware. It can transform a device's normal operating system to complex software that allows the hardware to interact with the operating system (os), completing all monitoring and decryption functions. Firmware can be involved in a wide variety of products, including consumer electronics and computer peripherals. A CPU, such as an ARM processor, handles the electrical components of 3D printers. These processors on a computer execute the basic system. The software firmware feature is the only method to get closer to the real system and is what allows the 3D printer to function.

List of Firmwares

- Marlin
- Klipper
- Prusa

1. Marlin

One of the most well-known and extensively used 3D printer firmware alternatives is Marlin. Many 3D printer manufacturers include or adapt Marlin firmware to work on their machines. Marlin's strengths include its high amount of customisation and extensive community support, with roots in Sprinter and GRBL (other firmware).

It is available in two versions: one for 8-bit boards and the other for 32-bit boards. The 32-bit version has more advanced and up-to-date functionality. Marlin's flexibility to change practically everything means you can use it to make your own 3D printers. Marlin is frequently used to control CNC machines and laser engravers.

2. Klipper

Klipper firmware is a newer and more feature-rich 3D printer firmware. Klipper's key feature is its ability to do computations quickly, resulting in quicker 3D printing rates. Klipper firmware may boost the speed of your 8-bit 3D printer to above 80-100 mm/s. It accomplishes this by utilising a second single-board computer, such as a Raspberry Pi.

"Smooth pressure advance" and "input shaping" are two characteristics that provide a very dependable and high-quality 3D printing experience. It may be used on a variety of Cartesian and Delta-style 3D printers with minimal extra hardware (other than the Pi). Klipper firmware is built in Python, but with a more straightforward coding style.

3. Prusa

One of the modified versions of Marlin firmware we mentioned previously is the Prusa firmware. It's designed to work with the Prusa 3D printer's Einsy Rambo boards. This means the firmware is only compatible with Prusa's own printers, but it's jam-packed with useful features and updated on a regular basis.

Prusa printers are among the top 3D printers available, with unique features including multi-material printing, mesh bed levelling, and TMC 2130 drivers. These functionalities benefit from firmware that has been adjusted specifically for them. Prusa firmware has only improved over time due to its open-source and free nature.

Steps to install custom 3D printer firmware

The following are the major stages to changing the firmware on 3D printer:-

(1) Using a USB cable, connect 3D printer to your computer.

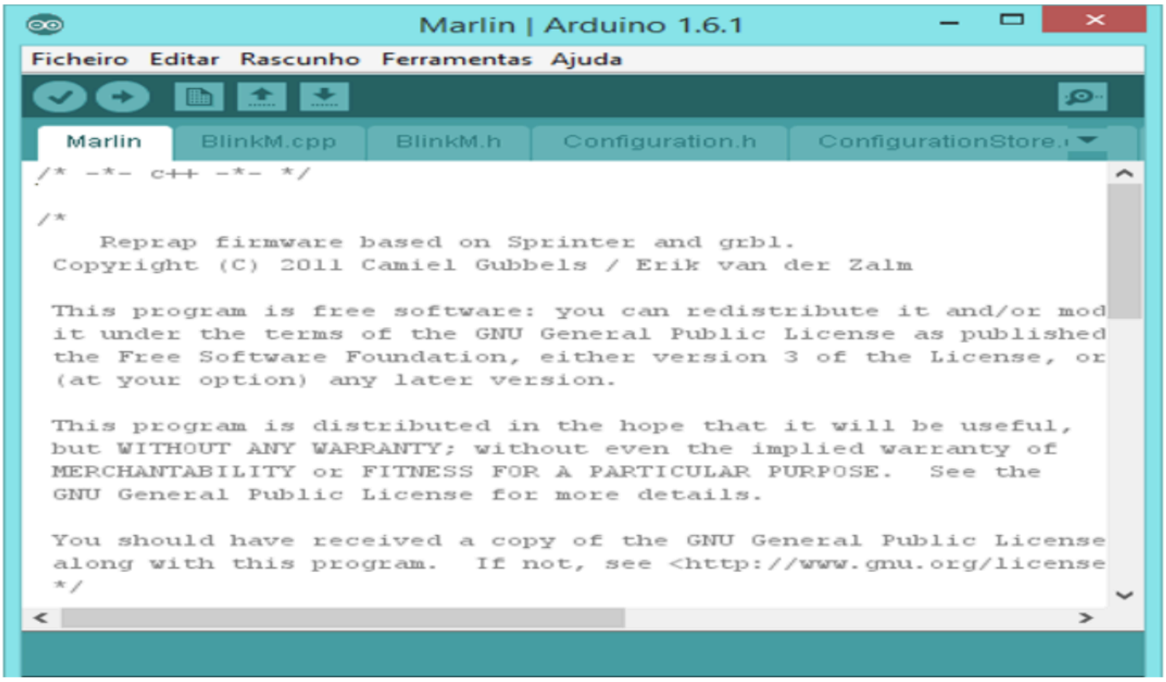

FIG 6.1:- PROGRAM OF ARDUINO

(2) In the Arduino IDE, open your firmware (in this case, Marlin).

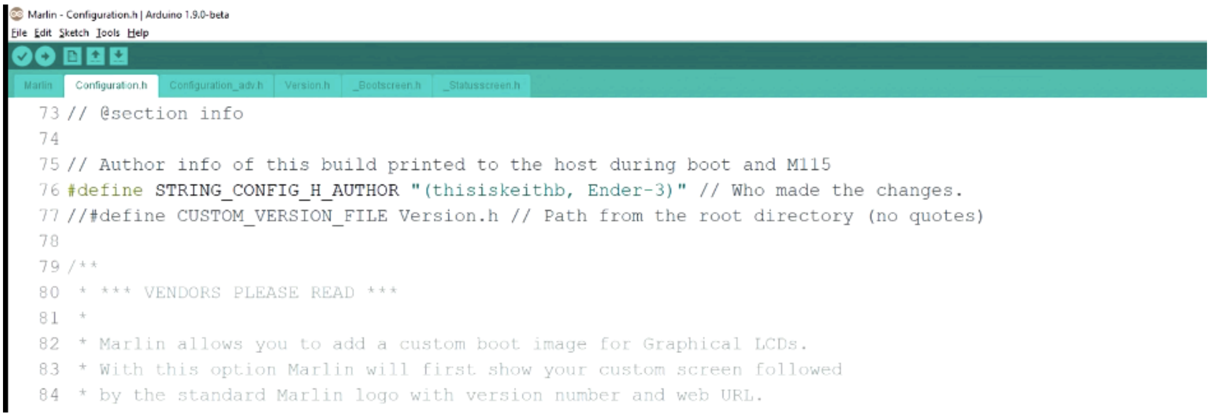

FIG 6.2:- MERLIN FIRMWARE

(3) Compile the merlin firmware and update the motherboard name in configuration.h file.

(4) In the files mentioned, user can initialise the unused pins, set/unset ports.

Marlin\src\pins\stm32f1\pins_CREALITY_V4.h
Marlin\Configuration.h
Marlin\Configuration_adv.h

FIG 6.3:- FILES TO BE UPDATED

(5) If you want to make any adjustments, you may do so immediately under the firmware's printer-specific area. (Instructions for making any changes may be found in the firmware itself.)

(4) Select your 3D printer controller board processor under the "Tools" area, and make sure the COM port is configured appropriately.

(5) Click the "Tick" symbol in the upper left corner after you're finished. This starts the compilation process. You'll get a notification that reads "Done Compiling" when the firmware has been built.

(6) Download and install the firmware on your 3D printer.

(7) In your 3D printer, initialise the EEPROM.

Software used for Designing the 3d Printer

1. Fusion 360

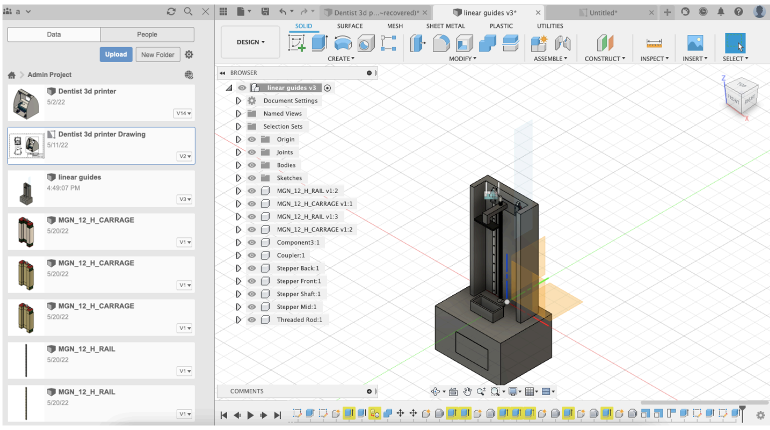

FIG 6.4:- FUSION 360 SOFTWARE WINDOW

Fusion 360[57] is a CAD/ CAM product development tool that runs in the cloud. Fusion 360 facilitates idea development, duplication, and interaction among the product development team's various locations. Fusion 360 is a complete software suite that combines organic modelling, mechanical design, and production. We most probably generate the STL file since it is suitable with 3d printers and offered in a range of formats that provide additional information about the model. Background computing is not needed to define data such as form, colour, or technology. Fusion enables any slicing application to retrieve G code for digital 3d models, enabling the design to be produced completely with the this software.

Software used for printing the models

1. Halot box

The most sophisticated 3D printer software in the world for slicing. Halot box is an environmentally friendly slicing programme, yet many users are unaware of its capabilities. Simply import the CAD model into the programme and set the print quality by hitting the software's print option. It's just like regular 2D printing. Halot box is essentially print software that can send a digital file in any format from any computer to a 3D printer. such that 3D printing understands itself and can print Halot box is free to download. It is the industry standard software for 3D slicers for resign based printers. When comparing Halot box to other 3D slicing software, it appears to be quite straightforward. Halot box has a lot of tools for slicing, but other software has limited options and tweaks. Halot box, on the other hand, provides more sophisticated options if you need them; it's just been built to be highly user-friendly. Halot box was created by Creality, a 3D printer business known for their precision, as seen by their hardware. Almost all of the settings and choices seen in the majority of other slicing tools are available in the Halot box programme.

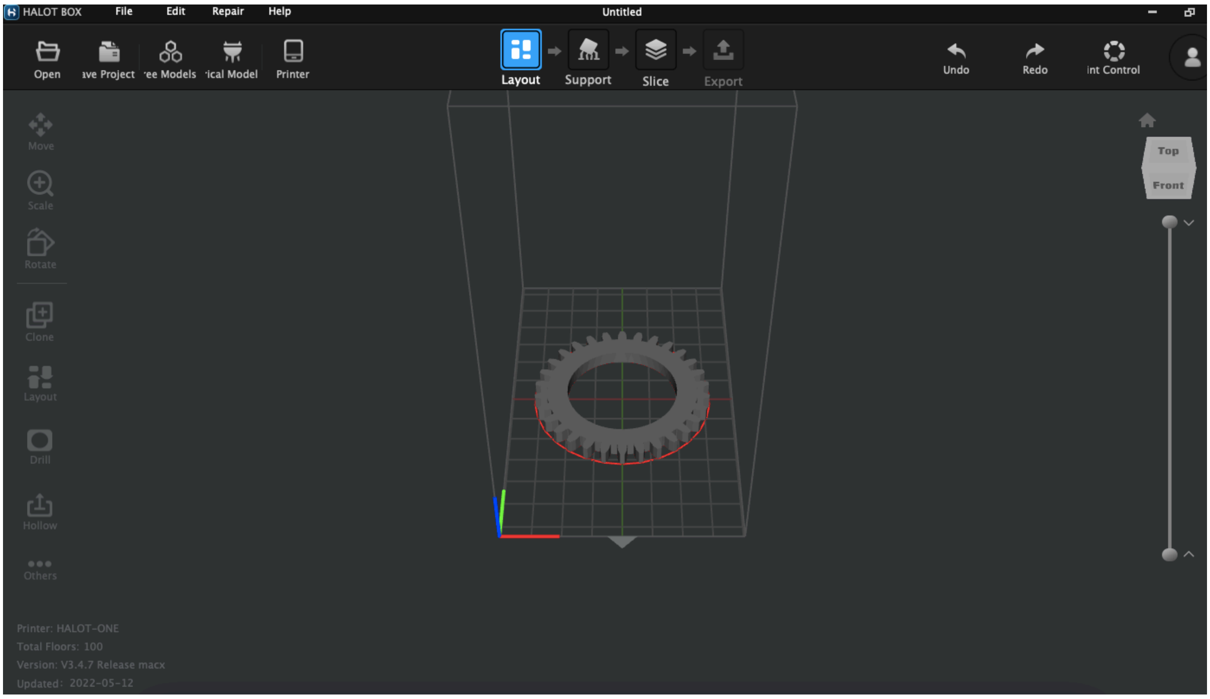

FIG 6.5:- HALOT BOX

We can adjust the settings according to what we want to print by altering a few quality and speed choices, and then Halot box will lay everything out for us. We'll just assume you've powered on your printer and loaded the resign. Halot box, which allows for seamless integration of hardware, software, and materials for the finest 3D printing experience, supports a variety of file formats including STL, 3MF, and OBJ. We utilise the STL file format in our 3D printer because the model is entirely developed in fusion 360 and the file format is STL. Halot box must convert every model we create for printing into instructions. The first thing you'll need is a 3D model, which you should export in STL format so that Halot box can read it. Halot box slices your models into print-ready slices in a matter of seconds. You may use printer settings to make any necessary modifications to a 3D printer.

CHAPTER-7
Hardware Implementation

Now that when we were satisfied by our design part, we started with hardware implementation. Dental 3d printer requires mechanical assemblies, we started by gathering tools and electronics stuff from local market and few items from online. A hack saw, driller, aluminium plates, linear railing, nuts bolts, motherboard, power supply were on the list.

We started by assembly of z-axis, on a aluminium plate of 5 cm in length, two slotted rails were engraved. Over which linear motion railing were welded.

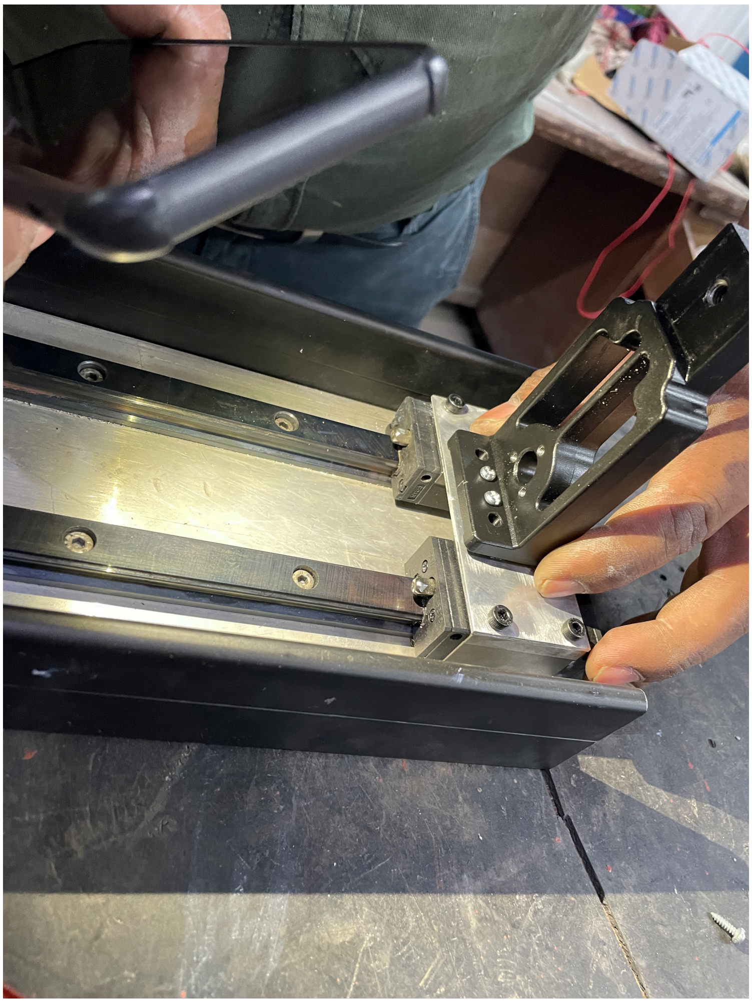

FIG 7.1:- DEPICTS MECHANICAL ASSEMBLY OF DUAL Z-AXIS

With enough friction[51][52][53] and both boxes sliding perfectly, we used a aluminium plate to make a right joint between them, then using a bracket 3d printable plate is attached through the stepper.

FIG 7.2:- BRACKET TO BE ATTACHED TO THE ALUMINIUM PLATE AND STEPPER MOTOR

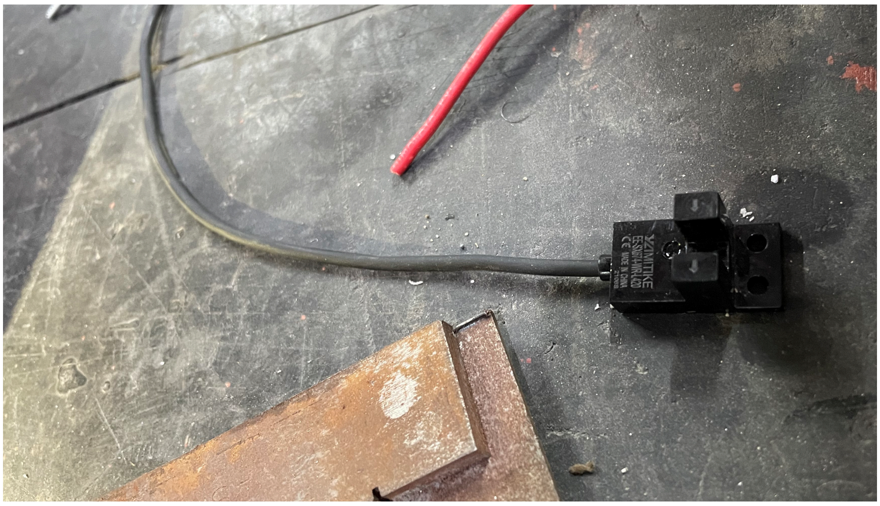

FIG 7.3:- IR LIMITING SWITCH TO LIMIT THE Z-AXIS HEIGHT

Once this was done, electronics was assembled into a pair of iron plates, and motor was installed. Carefully the light source and mirror was also installed producing light source falling on the monochrome 2K lcd screen.

Power Supply is the connected to the motherboard along with other peripherals. Power Supply is an important element to maintain proper current flow in the motherboard.

FIG 7.4:- ASSEMBLED 3D PRINTER

Once individual portions were finished, we assembled them using 4 M5 nuts, by driling holes in metal plate.

To have proper air flow, mini exhausts were installed.

FIG 7.5:- DEPICTS THE ASSEMBLED ELECTRONICS ITEMS

Now the mechanical assembly of 3d printer was ready, we decided to test some prints related to dental field only Resin 3D printers are perfect for prototyping and building effective dental mold and for their speed and accuracy. 3D printers are usually robotic robots in terms of performance. The device will not operate without computer-aided design (CAD) software. CAD software allows the construction of items and assemblies in a visible environment.

CAD software has been widely used in industrial construction, design, and manufacturing environments, as well as dentistry laboratories, and has become a standard part in many

FIG 7.6:- 3D SCAN OF HEALTHY JAW

dental practises.

FIG 7.7:- 3D SCAN OF UNHEALTHY JAW (MISSING TEETH)

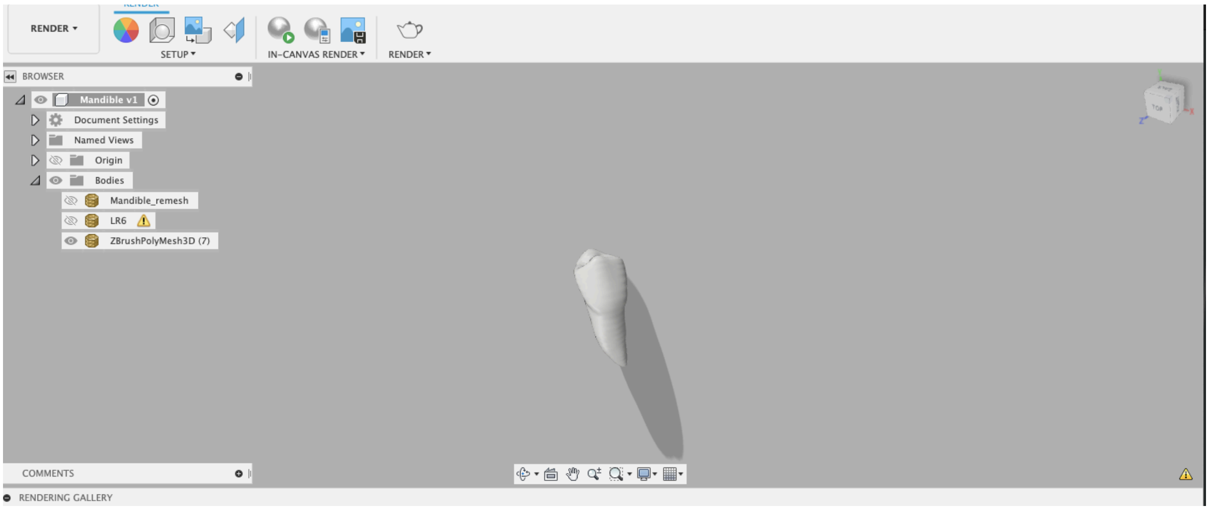

FIG 7.8:- 3D MODEL OF THE TOOTH TO BE INTEGRATED

The very first step to use 3d printers in dentistry is to acquisition of 3d patient model, this step would require 3d probe scanners to scan through the mouth.

FIG 7.9:- 3D PRINTED TOOTH IN HUMAN JAW

The next step would be to create a sty file of the jaw and import it in a CAD software to clean the model. This cleaned model is now imported to another software which mathematically generates a tooth for the missing place for proper fitting.

FIG 7.10:- 3D MODEL OF A TOOTH

This tooth model is now prepared to integrate into the patient's model by any suitable method.

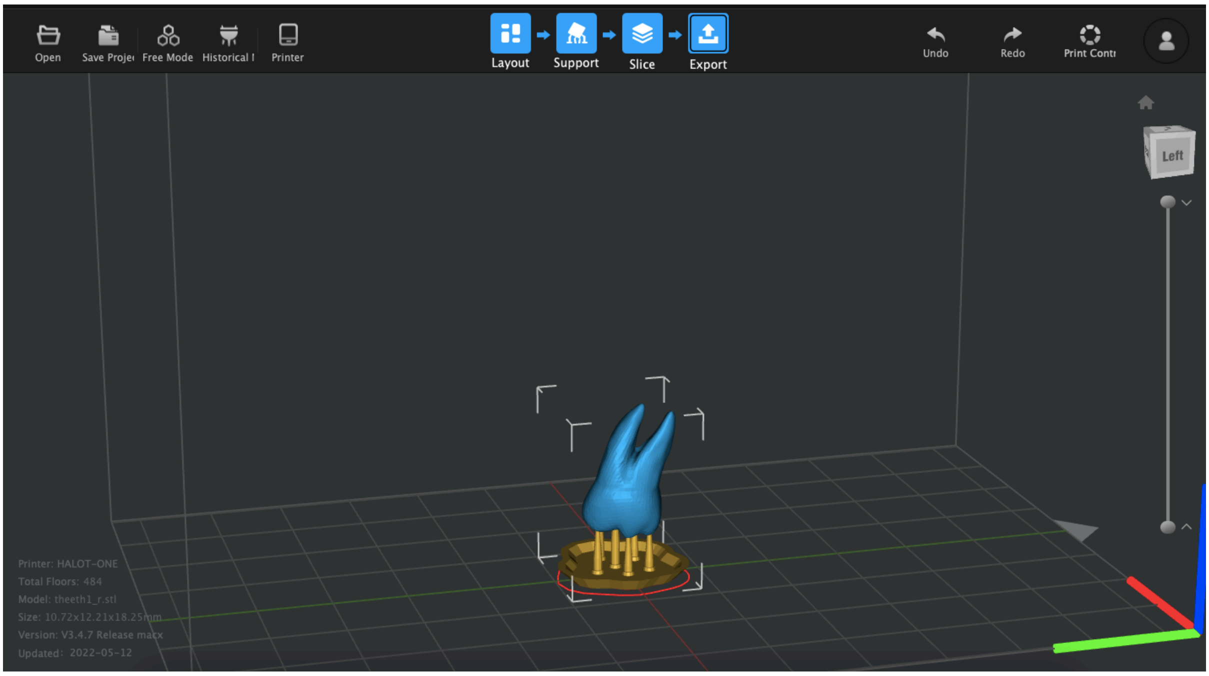

FIG 7.11:- SLICED MODEL OF TOOTH FOR PRINTING

Now that once we have the stl file for the jaw and tooth, we'll use slicing software to create a '.cxdlp' file which is read by our 3d printer. We'll be using halo box to slice the '.stl' file o the design

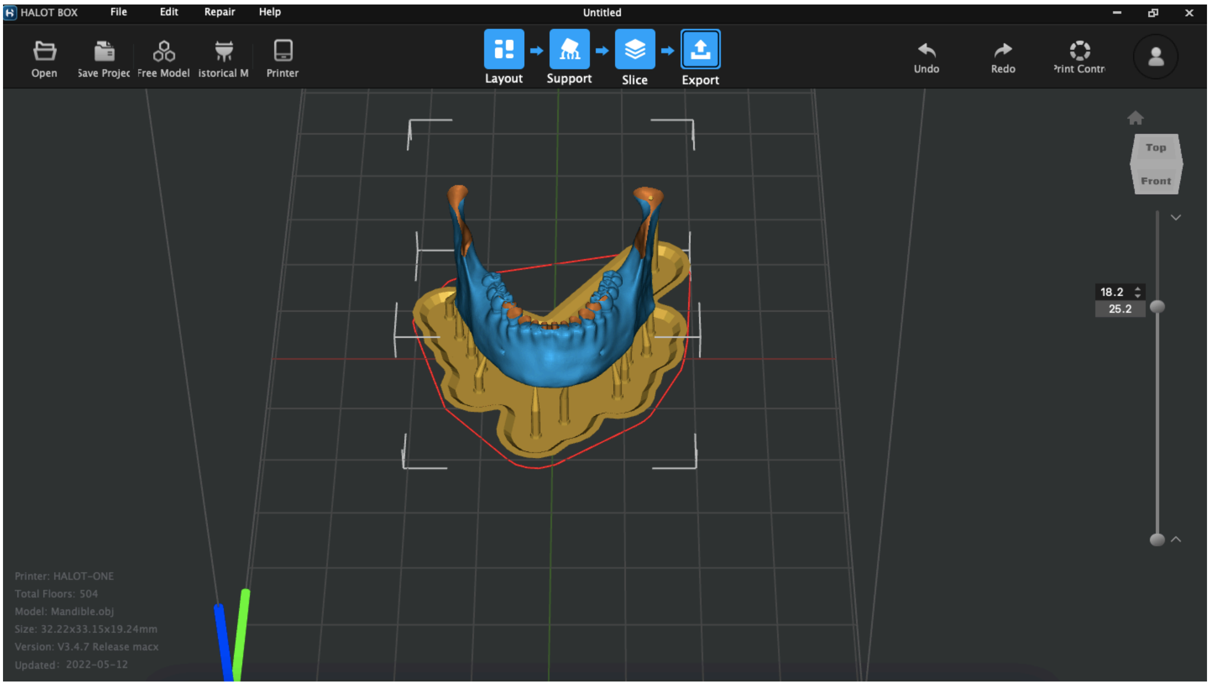

FIG 7.12:- SLICED MODEL OF HUMAN JAW READY FOR PRINTING

Once the required sliced files '.cxdlp' are generated, they are ready to be printed by our printer.

CHAPTER-8
CONCLUSION AND RESULTS

This project resulted in the creation of a dental 3D printer, which was finished successfully. Aluminum parts are used to make the structure sturdy and compact. The different elements' material selection is cost-effective. The use of a single vertical motor and a proximity sensor makes bed levelling simple, and the bed movement is monitored with micron-level precision. The deformation of the produced layer at high rates of printing is a problem with some 3D printers that employ larger prints. To circumvent this limitation, a novel method based on bed movement in Z has been created

Build Volume	221*221*404 mm
Method	LCD
Curing Speed	1-10s/layer
Power Supply	24V, 1.3 Amp, 100W
Z-axis type	Dual Slide Rails
Printing Filament	Polymer resign
Curing Wavelength	405nm
LCD pixels	1650*2560
Pinting speed mm/h	60mm
Print Size	127*80*160mm

TABLE 8.1:- MACHINE SPECIFICATIONS

Brand	Any cube
Shrinkage	7.1%
Curing time	2-4s
Elongation at breakage	14.2%
Tensile Strength	23.4Mpa
Hardness	79D

TABLE 8.2:- FILAMENT SPECIFICATIONS

FIG 8.1:- 3D PRINTED OBJECT 1

FIG 8.2:- 3D PRINTED OBJECT 2

FIG 8.3:- 3D PRINTED OBJECT 3

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