A review of Dental implant Stem manufacturing Techniques tailored to the patient's oral and Maxillary anatomy

Mahdis Parsafar

Department of Biomedical Engineering, Faculty of Paramedical Sciences, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran.
mahdis.parsafar@gmail.com

Pegah Javidfar

Department of Biomedical Engineering, Faculty of Paramedical Sciences, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran.
Pegah.javidfar80@gmail.com

Mohammad Ali Golparvar

Department of Biomedical Engineering, Faculty of Paramedical Sciences, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran.
Mohammadali.golparvar79@gmail.com

Abstract

Dental implants are a contemporary approach of replacing teeth that are missing. This process involves meticulous planning and consideration of various elements, including the choice of materials, size, measurements, implantation procedure, potential difficulties related to soft tissues, and the way of connecting the abutment screw. The implant base, also known as the fixture, functions as the foundation of the tooth in the lower jaw and is an essential element of dental implants. Titanium is commonly employed as an implant fixture because of its superior biocompatibility with the human body in comparison to other alloys such as zirconium oxide and cobalt-chromium-based alloys. Titanium alloy is the most ideal material for implant fixtures due to its resistance to corrosion, absence of excess, and conformance to PH criteria. Based on a comparative review of several 3D printer procedures, it can be concluded that using titanium-based technology is the most effective method for producing implants. The objective of the study is to manufacture dental implant bases that precisely match the shape and structure of the patient's jaw and oral anatomy.

Keywords: Dental Implant Fixture, 3D printers, corrosion, Titanium alloys, Different Methods of Manufacturing

1. INTRODUCTION

The market for implants produced using contemporary methods is expanding as a result of the increasing number of elderly individuals, the prevalence of lifestyle disorders, the potential drawbacks of transplantation, and the rising demand for bioactive ceramic implants[1]. A dental implant is a biocompatible medical device composed of metallic and non-metallic biomaterials. It is a dependable therapeutic option for restoring the teeth of patients who are partially or fully toothless. The placement of dental implants has become a widely accepted technique for replacing a single tooth in the mouth and restoring the functionality and aesthetics of teeth, resulting in numerous advantages. Dental implants are commonly designed to resemble a tooth root and are inserted into the jawbone. The abutment, which serves as the retaining piece, is positioned on the implant, while the crown is placed on top of the abutment. Using surgical techniques, we securely attach implants to the jawbone and then affix an artificial tooth to them, creating a tooth that closely resembles a genuine one. A dental implant is the most dependable option for replacing a missing tooth[2]. Dental implants are the main artificial teeth used to replace natural teeth roots. Among the different methods of replacing tooth roots, dental implants are regarded a comprehensive solution. Implants are heavily reliant on screws. The user's text is straightforward and precise. The fixture, sometimes referred to as the implant base, is a vital component of the dental implant that is positioned within the jawbone. Generally, the implants consist of hollow, integrated, perforated, flat-threaded, and cylindrical bodies, as determined by their design. The design of implant fixtures includes factors such as 1) the configuration of the thread, 2) the extent of the threads, and 3) the spacing between the threads. Threads enhance the initial stability of the fixture, and the greater their depth and number, the larger the contact area between the implant and the adjacent bone. In addition, the quantity of threads will have minimal impact on the velocity at which the implant fixture is inserted into the jaw. The success of dental implants relies on several crucial factors, including the initial and long-term stability and integrity. Additionally, the effectiveness of the implant design, such as the choice of material, dimensions, size, and implant method, plays a significant role. Complications arising from the surrounding soft tissue and mechanical issues, such as abutment design and the technique used for the abutment screw, [3]also impact the overall success of the implant. Fixtures have a cylindrical or conical shape. Implant fixings are predominantly composed of titanium metal. The efficacy of implant treatment is mostly contingent upon meticulous treatment planning, succeeded by accurate dental implant fixture surgery. The prosthesis stage is strategically designed to enhance the

predictability of treatment outcome. Utilizing patterns and surgical guidance to establish the ideal position and inclination for accurate implant placement serves as a guiding principle for the surgeon and can serve as an indicator of achievement. The surgical patterns serve as a guide for the surgeon to position the implants in a way that achieves the optimal balance between aesthetics, health considerations, and anatomical constraints. Additionally, these patterns ensure the required level of accuracy during the implantation[4] process. In general, implants are categorized based on their surface characteristics and the condition of the body they are placed in. Titanium is the primary component of dental implants, although there are three main types of materials that are often used to create implant alloys: stainless steel-based alloys, cobalt-chromium-based alloys, and titanium-based alloys. An essential criterion for selecting a metal implant material is its compatibility with the surrounding environment, meaning that it must not have any deleterious effects on the surrounding biological system. Dental implants utilize titanium and its alloys because of their advantageous composite qualities, such as corrosion resistance and high biocompatibility. Titanium is the primary material used in dental implants, but there are differences in their body design and surface materials. The choice of materials is vital in guaranteeing the steadfastness, longevity, and resilience of dental implants throughout their lifespan[5]. The production of dental implants using a titanium alloy with a distinct porosity structure is a promising approach to enhance the design of implant foundations. By employing a rapid additive manufacturing method, we are able to fabricate prototypes of dental implants that possess porosity (made from Ti6AL4V). Titanium and its alloys are widely regarded as the optimal biomaterials for creating dental implants due to their exceptional tensile strength, excellent biocompatibility, and ability to bond with bone. Nevertheless, the emergence of oral implantology has raised concerns over bone resorption caused by mechanical stress on bone tissue. Porous titanium alloys are widely acknowledged as appropriate for repairing bone deformities,[6] mostly because of their hardness, adaptability, and adjustable qualities. Rapid additive manufacturing (AM) technology provides a favorable method for producing personalized titanium dental implants. The rough and porous surface texture we expect to achieve will improve the initial fixation of the implant and facilitate superior bone integration. Computer-aided design and manufacturing (CAD/CAM) technology has rapidly advanced the creation of dental restorations in dentistry[7]. In the field of dentistry, technology known as CAM/CAD is utilized for multiple purposes, one of which is the fabrication of personalized dental implants. The fascination in metal additive manufacturing (AM), specifically selective laser melting (SLS-SLM), arises from its capacity to efficiently produce intricate metal objects with complex geometries. However, there are upcoming obstacles in the manufacturing process of producing top-notch (SLM) products specifically for dentistry use[8]. Initially, the Firstly, we must improve the quality of the product's surface by standardizing the laser process settings and using suitable surface finishing techniques. Next, we must ensure the precise dimensions and proper alignment of the dental restoration.Next, we aim to establish a clear and precise standard for dental implant construction strategies that improve the mechanical characteristics and ability[9] to withstand stress of dental structures using selective laser melting (SLM) technology. In order to optimize the application of cosmetic dental restorations, it is imperative to thoroughly investigate the relationship and assistance provided by the substructure's connection and support, known as SLM. Additionally, in addition, additive manufacturing (AM), sometimes referred to as 3D printing[10], accelerates the process of combining materials for creation by constructing 3D things layer by layer using digital data[11]. Implant dentistry is a highly effective method for treating patients who need dental implants. However, it is important to engage in meticulous planning prior to treatment. a highly effective approach for treating patients with dental implants is prosthetic implant dentistry. This method requires careful planning before treatment to ensure the accurate positioning of the three-dimensional implant in the jawbone. This enables the reestablishment of the prosthesis. Two scanning techniques, one conducted internally and the other externally in the mouth, produce a three-dimensional representation of the dental structure[12]. The stability of the connection between the fixture and abutment is vital in evaluating the accuracy of the prosthesis fit and the occurrence of mechanical issues[13]. The integration of nuclear medicine and engineering has resulted in a significant breakthrough in the medical profession in recent years. On the other hand, However, the conventional approach has several disadvantages. For example, challenges related to the fitting of implants and changes in the patient's oral state require increased focus, assurance, and ease during the building process. The patient needs a customized prosthesis. Another notable concern regarding patient-specific dental prostheses is the manufacturing technique. Manufacturing dental prosthesis can be challenging.

The conventional approaches to deploying prostheses have been ineffective in meeting the growing requirements for precision and intricacy[14]. The primary objective of developing contemporary dental implants is to ensure its efficacy in delivering functionality, aesthetic appeal, and stability that closely resemble that of natural teeth. One of the to prevent concerns such as fracture, loosening, and swelling after implantation, it is necessary to ensure a secure contact surface between the fixture and abutment in dental implants. The loosening of the abutment is a common problem that often results in patient unhappiness. The issue of screw loosening and failure[15], especially in cases of single-tooth replacement, persists despite many attempts to address it. Screw loosening can lead to complications including as patient-reported pain, periodontal infections, wounds, swelling, and instability of prostheses. Furthermore, according to Furthermore, the research indicates that in order to achieve optimal tightness, the maximum force used to tighten the screw should be 75% of the effort required to break the screw. Nevertheless, this particular design is impractical for oral use because the dimensions of the screw are contingent upon the size of the tooth. The bond between the bone and implant is limited by biological factors[16]. Utilizing engineering ideas in the mouth cavity will mitigate issues. This study presents a technique for using computer assistance to design and manufacture a dental implant that is customized to fit the patient's jaw and mouth anatomy. The goal is to create a dental implant base that prevents swelling, fracture, and loosening after it is implanted.

2. MATERIALS AND METHODS

Implant alloys typically comprise three primary categories of materials: stainless steel-based alloys, cobalt-chromium-based alloys, and titanium-based alloys. As previously stated, a fundamental criterion for selecting a metal material is its compatibility with the environment [17] meaning that it does not exhibit any hazardous effects on the surrounding biological system. For more than a century, scientists have conducted research on the introduction of different metals, such as aluminum, copper, zinc, iron and carbon steels, silver, nickel, and magnesium, into the human body. Stainless steel, particularly the low-carbon variant known as type 316, is a popular option for implant materials because of its exceptional mechanical strength and notable resistance to corrosion in various harsh conditions. During the same period, the dental and orthopedic sectors initially introduced molybdenum-cobalt, chromium-cobalt,

and chromium alloys because of their ability to resist corrosion. Dental implants presently employ titanium and its alloys as materials that are resistant to corrosion [18], and their utilization is steadily expanding and continuing to rise. Titanium alloys, including Ti-6Al-4v, Ti-5Al-2.5Fe, and Ti-6Al-7Nb alloys, exhibit advantageous mechanical strength and corrosion resistance properties due to their diverse structures. Titanium and its alloys offer a significant benefit in their non-reactivity due to the formation of a protective foundation that prevents penetration. These materials are highly sought after for creating dental and orthopedic implants [19] due to their favorable composite characteristics, including low specific density, high strength-to-weight ratio, great flexibility, exceptional corrosion resistance, and outstanding biocompatibility. The manufacturing and production techniques employed for medical parts, prostheses, and dental implants have a substantial influence on their mechanical and environmental characteristics. There are several manufacturing techniques for these parts, with the most significant ones being isothermal forging, machining, casting, and additive manufacturing (AM) or 3D printing technologies. Each method has its own popularity over different time periods. I have existed. The progress in technology, equipment, and computer utilization has resulted in a rise in rapid prototyping [20]. Three-dimensional printers are a crucial tool for rapid prototyping. Three essential processes in 3D printers, generally referred to as additive manufacturing methods, are FDA, SLM, and SLA. These printers can utilize several ways depending on factors such as the material, speed, and precision. Additive manufacturing (AM), a technique that builds objects layer by layer, is used to create three-dimensional models of complex structures. The (AM) approach is used in several areas of dentistry to produce dental models, surgical guides, and a range of dental veneers [21]. In recent years, there has been a significant increase in the utilization of computer-generated and produced dental prosthesis. CAD-CAM technology typically comprises three sequential steps: The three main steps involved in the process are: 1) data collecting or digitalization; 2) data processing using computer-aided design (CAD); and 3) manufacture using computer-aided manufacturing (CAM). There are two techniques for three-dimensional manufacturing, known as computer-aided manufacturing (CAM) [22]. These techniques are the subtractive method (SUM) and the additive method (AM). 1) The reduction method involves using a lathe to grind the material block. This technique shortens the duration of treatment and offers numerous benefits for

dentists, patients, and laboratory staff. Nevertheless, there are drawbacks associated with it, including excessive material wastage, thickness constraints, reduced precision in capturing intricate features due to the dimensions of the milling cutters, and the exorbitant cost of the equipment. The incremental method, commonly referred to as rapid prototyping in 3D printing, involves the gradual addition of material layer by layer. The incremental approach (AM) provides superior design freedom, exceptional accuracy in capturing details, and less material waste, in contrast to the reduction method. The additive manufacturing (AM) approach is employed for the fabrication of intricate and advanced structures. The additive technique is an alternative to the subtractive method, which mostly utilizes powder- or liquid-based materials to produce solid 3D objects. The variables that contribute to the progress of additive manufacturing technology are rapid prototyping, fabrication of massive structures, reduction of manufacturing flaws [23], and enhancement of mechanical qualities. Typically, the procedure (AM) has four distinct steps: The software generates a digital 3D model by utilizing data from intraoral scanners or data processing. Subsequently, the 3D model is partitioned into many 2D layers, which are then subjected to two rounds of 3D printing to produce the ultimate result. 3) The last step of the procedure (AM) includes creating a digital 3D model from pictures (MRI), CBCT, or extraoral scanners using software (CAD), translating the data format (CAD) to STL, and then using different established methods [24] for (AM) to produce the final output, layer by layer. Tessellation refers to the procedure of dividing a three-dimensional structure into two-dimensional pictures and subsequently recreating it. The precision of the end product is contingent upon the thickness of each individual layer, which ranges from a few micrometers to one millimeter. The ultimate accuracy of a structure is influenced by the choice of materials, the type of printer used, and the level of complexity in the design [25]. Various techniques exist for 3D printing. The American Society for Testing and Materials (ASTM) categorizes additive manufacturing technology into seven distinct processes: 1) Tank photopolymerization refers to a process known as DLP-SLA, where a tank

is used to solidify a liquid resin using light. 2) Additive welding or material extrusion, also known as FDM, involves the process of adding material layer by layer to create a 3D object. 3) Powder bed fusion (PBF), also known as selective laser melting (SLM) or selective laser sintering (SLS). 4) 3D printing, specifically using glue injection. 5) Injection of material 6) Energy delivery in a straight and unobstructed manner in the following sections, we will provide a detailed explanation of sheet manufacture for each respective process [26]. The initial technique is tank photopolymerization, which relies on laser polymerization and employs ultraviolet light (UV) or an electron beam to trigger the resin and monomer's chain reaction. Another technique for tank photopolymerization involves the utilization of liquid raw materials, which encompass photopolymers such as polyamides, elastomers, pure polymer resins, and composite resins. The manufacturing platform is situated within a reservoir of liquid photopolymer. The construction platform ascends and emits light, so accomplishing polymerization and forming the initial layer. To generate more layers, the construction platform lowers and immerses itself into the tank, enabling the layer's surface to be coated with liquid polymer. This technique iterates as the platform shifts. The procedure continues until it finishes all the layers and generates the 3D model[27]. Ultimately, the use of heat or light processing may be necessary in order to enhance the level of strength. (SLA) printing provides exceptional quality and clarity, but it demands a substantial investment in both time and money. Additionally, the selection of materials [28]for (SLA) printing is limited. Conversely, the resin is allergic and induces inflammation upon contact with the eyes and skin. The thickness of a layer is determined by the energy and exposure of the light source. Dentistry employs selective laser melting (SLM) technology to fabricate various dental components, including implants, casts, totally removable prostheses, temporary veneers, cast patterns, and metal frames. The digital light processing (DLP) and stereolithography (SLA) techniques share the same printing method and materials (figure1). However, SLA employs a laser for polymerization, whereas (DLP) relies on a digital projector.
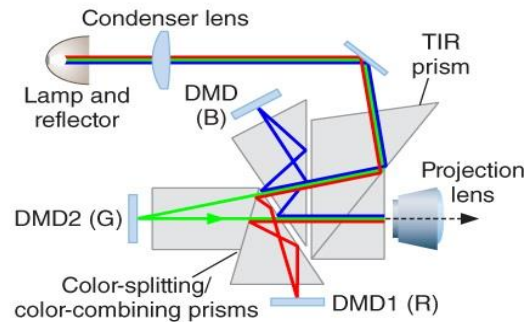
Figure 1: Schematic view of the DLD process of an additive manufactory

This approach functions at a higher velocity than SLA. The second procedure entails the fusion or ejection of materials. This technique employs a filament composed of a thermoplastic polymer for the purpose of 3D printing. Acrylonitrile butadiene styrene (ABS), polylactic acid (PLA), and polycarbonate are the predominant polymers in use. We subject the filament to heat until it reaches a semi-liquid state, and then proceed to construct the required model by adding layers one at a time. The fundamental characteristic of this technology is the thermoplastic nature of the polymer, which binds the layers together during the printing process and solidifies them at ambient temperature. Figure2 show the process of printing. The material should have a low melting point and, once melted, possess adequate viscosity to ensure smooth flow and easy extrusion from the nozzle[29]. Conversely, it must possess sufficient strength to uphold the subsequent layers. The mechanical properties of the printed material are primarily influenced by layer thickness, diameter, filament orientation, and porosity.
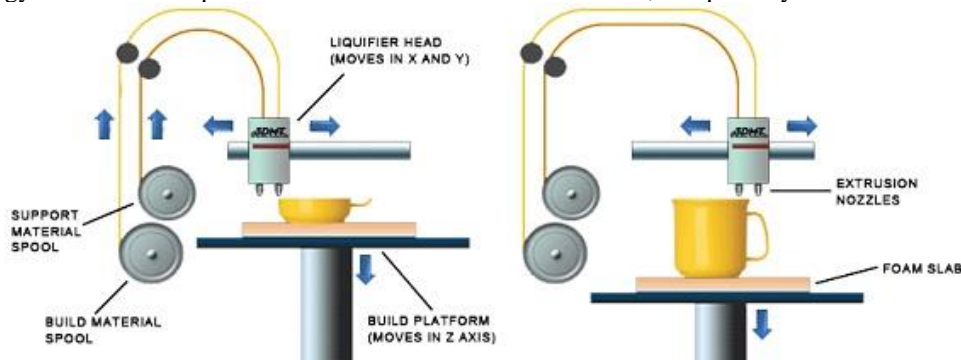

Figure 2: Schematic view of the FDM process of an additive manufactory

The primary benefits of this method are its affordability, fast execution, and straightforward procedure. This method is more efficient than SLA and more cost-effective than DLP. The disadvantages of this approach encompass inadequate mechanical strength, a visibly layered look, subpar surface quality, and a restricted range of thermoplastic materials. The advancement of fiber-reinforced composites has enhanced the structural integrity of models printed using Fused Deposition Modeling (FDM) technology. The primary obstacles in utilizing these composites are fiber orientation, matrix-fiber bonding, and porosity[30]. The third technique entails powder bed fusion. This technique entails evenly distributing a fine coating of powder onto a screen. A laser or liquid binder is used to fuse the particles together in each layer. We stack these plates vertically to form a three-dimensional product. Afterwards, a vacuum is used to eliminate the powder additions, and if needed, filtration is carried out to finish the final processing of the details[31]. Liquid binders are employed in the powder bed fusion process during high-temperature fusion, whereas selective laser melting is utilized during low-temperature fusion. Selective laser melting (SLM) and selective laser sintering (SLS) are two different methods of connecting powder grains in additive manufacturing, depending on the materials used and the desired application of the final

product[32]. (SLS) involves connecting the powder grains through surface heat, whereas (SLM) involves complete melting of the powder grains. The utilization of Selective Laser Sintering (SLS) enables the printing of a wide range of polymers, metals, and alloys. [33]In selective laser sintering (SLS), the laser does not completely liquefy the powder, but rather uses surface heat to fuse the layers of powder together (figure3).
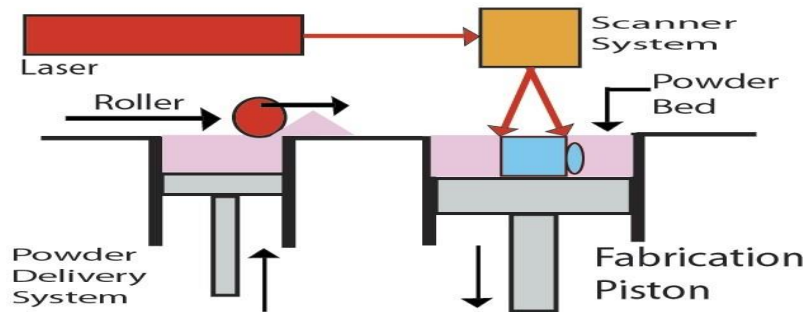

Figure 3: schematic view of the SLS process of an additive manufactory

Contrary to (SLS), the direct laser sintering of metals (SLM) is limited to specific metals like steel and aluminum. (SLM) achieves complete fusion and bonding of the powder (figure4), resulting in a significant improvement in its mechanical strength. Selective laser melting is a type of additive manufacturing technology.
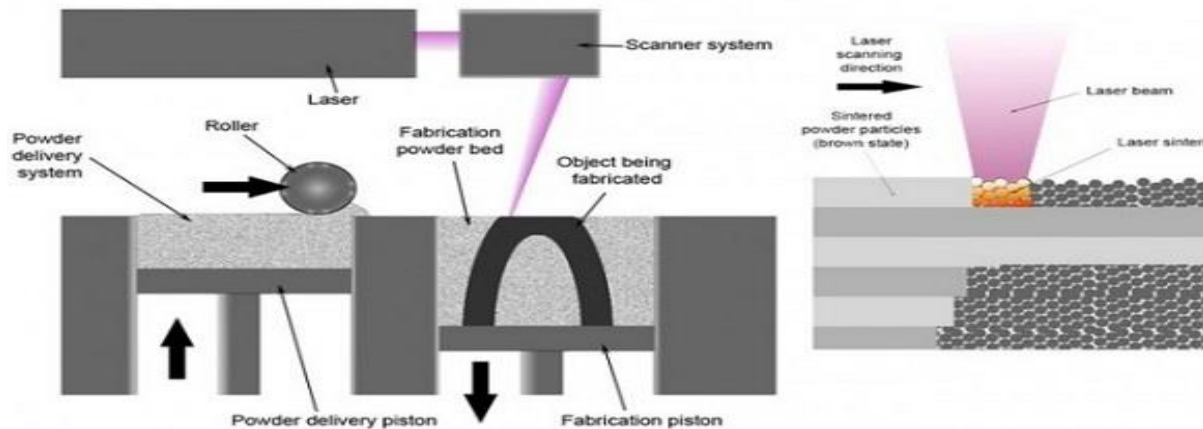

Figure 4: Schematic view of the SLM process of an additive manufactory

[34]Selective laser melting is an additive manufacturing technique that utilizes three-dimensional data and a high-power laser beam to construct three-dimensional metal objects. This process involves melting metal powders and joining them layer by layer.

3. DISCUSSION AND CONCLUSION

The AM approach is utilized in various sectors of dentistry, such as tissue engineering, implants, maxillofacial surgery, and prosthetics. One of the initial applications of CAD-CAM technology was to generate precise anatomical models and surgical guides, aiding surgeons in simulating surgical procedures prior to the actual operation. According to the study and materials cited, the use of 3D printers is a highly effective way for producing a dental implant foundation that accurately matches the patient's jaw and mouth anatomy[35]. The widespread adoption of 3D printers in dental implant manufacture has had a substantial impact on tooth reconstruction in modern dentistry. As stated before, 3D printing utilizes a technique of building layers to fabricate detailed 3D models. This technology includes a diverse range of techniques, substances, and machinery. Our objective is to determine the most appropriate manufacturing processes for patients by carefully evaluating and

questioning the benefits and drawbacks of each option, utilizing knowledge from engineering and medical sciences. We employ the 3D printing method to accelerate the treatment procedure[36]. When selecting the appropriate printing method, it is necessary to take into account the biological characteristics of the material, its availability, the desired level of detail in the final product, and the time needed. Currently, the focus of analysis and development in the field of 3D printers revolves around enhancing the printing speed, broadening the range of materials that may be used, and refining post-processing techniques. The reservoir photopolymerization method (SLA), the material extrusion method (FDM), and the powder bed fusion method (SLM-SLS) are the predominant manufacturing methods for implant bases[37]. These methods have gained popularity due to technological advancements and changes over time. 3D printing utilizes three distinct material categories: metals, ceramics, and polymers, each necessitating a unique printing technique. The Fused Deposition Modeling (FDM) process gradually heats the filament until it reaches a partially solid state, and then constructs the desired object by adding one layer at a time. This approach yields more precise differentiation, albeit at a slower pace and with higher associated expenses. Although polymer threads are commonly used in this process, there are other techniques available that allow for the utilization of a broader variety of materials, including metals. The FDM technique[38] is widely utilized in production due to its simplicity, high speed, and cost-effectiveness compared to other methods. The polymer is fortified by incorporating elements to enhance its strength, resulting in the fabrication of composites that are reinforced with fiber particles and nanoparticles. Nevertheless, the items manufactured using this technology exhibit inferior mechanical qualities and manufacturing quality compared to those made using the SLS and SLA procedures.[39] Although the AM method has its advantages, there are several downsides that require additional research and development in order to efficiently apply this technology in many industries. In the photopolymerization process, a tank is utilized, similar to the approach used for polymers. However, in the SLA or DLD method, building is carried out using resins and photopolymers instead. In this procedure, the building platform is positioned within a photopolymer tank. It is then elevated and positioned in front of a UV or digital (LED) laser to undergo drying and preparation for the following layers. We iterate this procedure till [40]we generate the ultimate outcome. Although this procedure is highly accurate,

it also poses some obstacles. Initially, employing this technique necessitates a significant amount of time and necessitates subjecting the material to heat treatment subsequent to its production in order to enhance its durability. Conversely, the resin is allergic and induces biological complications. Currently, dental implants utilize this technique because of its exceptional accuracy and production quality, despite the fact that it takes longer than the FDM approach. Powder bed fusion is a commonly employed process that we have previously discussed in our writings. The Powder Bed Fusion (PBF) technology achieves the fusion of powder grains at elevated temperatures by the utilization of liquid binders. In addition, the powder bed fusion approach utilizes the selective laser melting process at low temperatures[41]. The production process details exhibit modest variations depending on the specific material employed, such as polymers, ceramics, and metals. Selective laser melting (SLS) utilizes the laser's surface heat to fuse the powder grains together, without causing them to fully liquefy. The SLS technique employs CO_2 lasers to generate the required thermal energy for polymers, ceramics, and other metals[42]. Selective laser melting (SLM) is a method that melts and connects powder grains, as discussed earlier. The process of Selective Laser Melting (SLM) can only be used with metals, specifically stainless steel and titanium alloys. This procedure employs lasers (specifically Nd: YANG lasers) that have sufficient power to fully liquefy the granules of metal powder. Nevertheless, the majority of SLM devices currently employ [43]fiber lasers due to their cost-effectiveness in terms of purchase and maintenance, higher energy efficiency, and superior beam quality compared to Nd:YYAG lasers. The selective laser melting (SLM) technique enables the fabrication of implants using biocompatible titanium powder. Calcium and phosphate can combine to create implants that can be easily absorbed by the body. The selective laser melting (SLM) process involves melting tiny layers of finely atomized metal powder that are evenly spread on a substrate plate, usually made of metal, using a coating mechanism. The melted powder is then attached to a moving table. The vertical axis, sometimes known as the Z-axis, is currently not in operation or unavailable.[44] The process is conducted within a chamber that maintains a highly regulated atmosphere, employing an inert gas like argon or nitrogen with an oxygen concentration of less than 500 parts per million. Following the deposition of each layer, a high-intensity laser beam is used to specifically liquefy each individual cross-section of the component's shape. This is achieved with a high-power laser beam, often a fiber laser. The

laser energy is sufficiently powerful to induce complete melting of the particles, resulting in the formation of a solid metal. Manufacturers iterate this procedure, adding one layer at a time, until the piece is finished. Manufacturers have replaced the (CO_2) laser with a (Nd: YAG) laser in SLS, resulting in a considerable improvement in the metal powder's absorption. One significant benefit of SLM over SLS is the utilization of an f-theta lens to reduce beam distortion[45] during scanning and to manage the low-oxygen atmosphere. In addition, the utilization of an f-theta lens throughout the production process removes the requirement for substantial time and furnace expenses for reinforcing the product after manufacture, leading to a more compact final outcome. Nevertheless, as a result of the limited scanning rate, the duration of the construction process has been prolonged. In order to enhance the quality of the laser, it is necessary to increase the energy level, utilize a laser of greater cost, and employ a laser with higher power. The drawbacks of the (SLM) approach include the instability of the molten pool, which leads to surface roughness and the production of interior pores. Additionally, this method results in increased residual stress[46], increasing the danger of delamination and distortion that might damage the base plate. An alternative approach involves fabricating implants with the use of 3D printers, specifically Electron Beam Melting (EBM) technology. Like (SLM), the (EBM) technique employs a concentrated electron beam (figure5) scan across the thin layer to provoke localized melting and solidification at each segment. The elevated temperature during this process minimizes the remaining strains resulting from the cooling of the liquid pool and the layer below. In addition, we produce (EBM) parts within a vacuum chamber to prevent any interference from oxygen and other chemical substances present in the atmosphere, thus preserving the integrity of the parts. The vacuum technique reduces residual stress and distortion to a minimum.
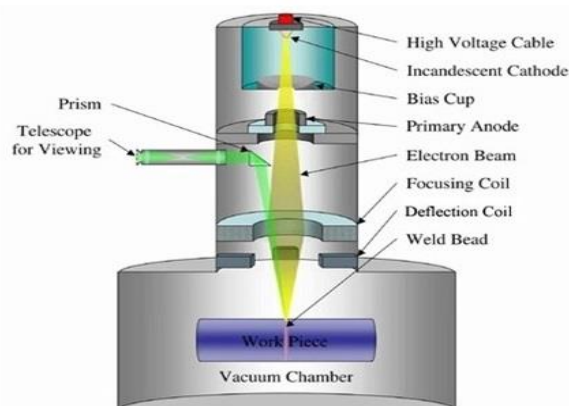

Figure 5: Schematic view of the EBM process of an additive manufactory

The hardness[47], strength, and ultimate tensile strength of SLM implants surpass those of EBM devices. In contrast, objects produced by EBM demonstrate greater elongations compared to those formed by SLM. The electron beam has several advantages over the laser beam. It may be deflected at a higher speed through the electromagnetic lens, and the focussed beam allows for precise control of the high input energy. These conditions facilitate alterations in the structure of the powder layer, encompassing a broad spectrum of liquid phase sintering to supplement the particles' melting or melting layer. Electron beams possess a greater energy density in comparison to laser beams, resulting in decreased manufacturing time and thereby lowering production costs. The electron beams' high energy elevates the temperature of the powder bed (EBM), ultimately resulting in the complete fusion of the metal powder. As a result, this process enables the creation of solid components with reduced porosity and more control over their mechanical characteristics. Unlike other methods of additive manufacturing, such as laser sintering, the EBM process has the ability to create parts that are completely fused and dense[48]. The EBM technique has effectively tuned the qualities of resistance, fatigue, and elastic modulus of the alloy to assure compatibility with bone. The effective implementation of this technology in the production of implants has led to a longer lifespan for the implant base, greater rehabilitation capabilities, and enhanced performance of the implant[49]. Therefore, considering the aforementioned information and

comparing it with different manufacturing techniques, the utilization of the 3D printer method enables the customization and personalization of implants. This allows for the adaptation of the implants to the doctor's diagnosis and the specific anatomy of the patient's jaw and mouth. The utilization of 3D printing enables the implantation of personalized dental implants with little wastage and optimal patient satisfaction. 3D-printed dental implants not only merge with existing teeth but also preserve their healthy structure and enhance their functionality. Furthermore, the utilization of 3D-printed dental models enables dentists to accurately determine tooth movement and achieve precise alignment during dental implant procedures. Assistance required during surgical procedure. The numerous benefits of 3D printing make it a compelling choice for dental professionals seeking enhanced efficiency and accuracy in their procedures. 3D printing enables additive manufacturing technologies that simplify the production of dental implants, including personalized screw implant restorations. This method facilitates the meticulous customization of dental implants to more accurately conform to the patient's oral cavity, hence improving the implant's performance and comfort[50], while also preserving a natural aesthetic appearance. This manufacturing approach is characterized by its superior speed, precision, and cost-effectiveness compared to conventional procedures, while also providing opportunities for customization. Dental implants are produced using 3D printing technology and a range of sophisticated materials such as stainless steel, titanium, titanium alloys, and cobalt-chromium. Titanium is frequently chosen because it is cost-effective and compatible with living organisms. Titanium exhibits a high level of compatibility with various computer-aided design and manufacturing (CAD-CAM) systems, hence making it extremely suitable for use with additive manufacturing (AM) processes[51]. Furthermore, its mechanical characteristics, including as exceptional hardness and rigidity, render it particularly well-suited for fabricating dental implants. Consequently, titanium alloys are used in conjunction with other materials to substitute metal components, resulting in a lighter final prosthesis while preserving its strength. In summary, the AM approach has significant potential in the field of dental implants since it allows for the use of a wide range of materials that provide enhanced comfort, precision, and aesthetics. Studies suggest that titanium implants are the most efficient form of additive manufacturing (AM) dental implants. Ti64 is a very suitable material for 3D printing dental implants because of its exceptional strength-to-weight ratio,

good resistance to corrosion, and favorable biocompatibility profile during manufacture[52]. One of the key benefits of 3D printing is its capacity to produce personalized objects with greater accuracy compared to conventional techniques. The meticulousness in the production process leads to prostheses that precisely conform to the unique anatomy of each patient, guaranteeing exceptional comfort and functionality. In addition, the AM procedure offers enhanced control over the shapes and substances employed, leading to decreased production duration and improved longevity and dependability of the product[53]. Human jaws display notable variations, with the left jaw of each individual different from their right jaw, which necessitates the use of customized components in the dental industry. Utilizing customized implants enables the practitioner to employ implants that precisely fit the patient's jaw[54] and mitigate numerous deficiencies associated with the usage of standard implants. Standard implants may include faults such as texture problems, incorrect implant angle, wrong load distribution, and cosmetic issues. Hence, it is important to highlight that the utilization of personalized implants is only suitable in cases when the production technique is gradual, and customization through alternative manufacturing processes is not feasible[55]. This is due to the fact that even the slightest alteration in the ultimate size of the implant can have a substantial impact on its functionality. It hinders osseointegration, the process of fusing and strengthening the implant foundation in the gums, which is necessary for the dentist. Personalized implants[56] eradicate the issues associated with traditional procedures and enhance the efficacy of implant treatment. Specialized or tailored implants offer a preferable alternative to ordinary implants due to their ability to match the size and characteristics of an individual's jaw bones, as well as their exact alignment with CT scan images of the patient's jaw. Conventional implants exert reduced stress on the junction between the implant and the bone[57], leading to a more robust connection between the implant and the bone. As a result, the implant treatment has a shorter duration and a better success rate. Furthermore, the utilization of personalized implants considers the patient's significant inclination towards aesthetics. The new personalized implant design process is now available to all persons requiring a dental implant, providing them with significant benefits. Furthermore, the ongoing development of this methodology will further improve the quality of treatment.[58]The novel approach of personalized implant design is an optimal solution for creating an implant that precisely

conforms to the patient's jaw and mouth anatomy. This technique effectively resolves the issues associated with conventional and existing implants, while also reducing the duration required for the implant to integrate with the bone.

4. RESULTS

Research and studies in the field of dental implants have shown that using additive manufacturing technology (AM) and alloys is highly effective in creating dental implants that accurately match the anatomy of a patient's jaw and mouth. The material in question is titanium. By utilizing titanium alloys, we are able to tailor the implant to the specific requirements of the doctor's diagnosis, the patient's wants, and the distinct architecture of each individual's jaw. This technique and material effectively mitigate issues such as loosening, fracture, and corrosion for the patient, while ensuring a precise fit of the implant to the patient's jaw and mouth architecture. Hence, the manufacturing processes known as Selective Laser Melting (SLM) and Electron Beam Melting (EBM) are considered very efficient approaches for fabricating personalized implants using titanium alloys, as elucidated in the preceding sections. These two procedures enable us to tailor the end result based on the doctor's diagnosis and the patient's requirements. The difference between these two manufacturing processes (AM) is based on the use of inert gases to create a non-reactive manufacturing environment, as well as the process of melting the powder grains. Within our SLM (Spatial Light Modulator), we utilize high-power lasers, specifically N.In our selective laser melting (SLM) process, we employ high-power lasers such as ND:YAG or fiber lasers to heat metal powders until they melt. Additionally, we produce a non-reactive atmosphere by introducing inert gases like argon and nitrogen. We carefully control the atmospheric pressure to maintain it at one unit and ensure a low oxygen content. However, the EBM approach utilizes a vacuum environment instead of inert gases in order to create a non-reactive atmosphere. This technique utilizes an electron beam, rather than high-power lasers, to provide the required energy for melting the metal powder grains. Although these two procedures have distinct characteristics, they both enable us to personalize or tailor. Prioritizing the doctor's diagnosis is the initial step in picking the proper approach. Furthermore, it is essential to take into account issues such as the ease of access to the selected method and the costs associated with manufacturing. The technique's availability is significant due to the presence of multiple patients residing in various places. There is uncertainty over the geographical place in question. During the second phase, he computed the disparity in expenses between these two building techniques, taking into account the relevant aspects. It is important to acknowledge that the production approach known as additive manufacturing (AM), which utilizes advanced scientific principles, provides both cost advantages and improvements in quality, while also making the patient's treatment procedure more efficient. Ultimately, the research demonstrates that the utilization of the additive manufacturing technology, specifically the SLM and EBM processes, not only improves the quality of dental implants customized to fit the patient's jaw and mouth architecture, but also simplifies the production process and sit has facilitated customization to cater to the requirements of diverse patients.

References

[1] B. Staniewicz-Brudnik, A. Stwora, J. Maszybrocka, G. Skrabalak, and E. Bączek, "The technique of selective laser sintering (SLS) in the design high-porous ceramic implants," *Mechanik*, no. 5–6, pp. 540–541, May 2016, doi: 10.17814/mechanik.2016.5-6.76.

[2] K. Liaw, R. H. Delfini, and J. J. Abrahams, "Dental Implant Complications," *Seminars in Ultrasound, CT and MRI*, vol. 36, no. 5, pp. 427–433, Oct. 2015, doi: 10.1053/j.sult.2015.09.007.

[3] F. J. Manzano-Moreno, F. J. Herrera-Briones, T. Bassam, M. F. Vallecillo-Capilla, and C. Reyes-Botella, "Factors Affecting Dental Implant Stability Measured Using the Ostell Mentor Device," *Implant Dent*, vol. 24, no. 5, pp. 565–577, Oct. 2015, doi: 10.1097/ID.0000000000000308.

[4] E. Moslehifard and S. Nokar, "Designing a Custom Made Gauge Device for Application in the Access Hole Correction in the Dental Implant Surgical Guide," *The Journal of Indian Prosthodontic Society*, vol. 12, no. 2, pp. 123–129, Jun. 2012, doi: 10.1007/s13191-011-0104-7.

[5] A. Vissink, F. Spijkervet, and G. Raghoebar, "The medically compromised patient: Are

dental implants a feasible option?," *Oral Dis*, vol. 24, no. 1–2, pp. 253–260, Mar. 2018, doi: 10.1111/odi.12762.

[6] F. Yang *et al.*, "Laser beam melting 3D printing of Ti6Al4V based porous structured dental implants: fabrication, biocompatibility analysis and photoelastic study," *Sci Rep*, vol. 7, no. 1, p. 45360, Mar. 2017, doi: 10.1038/srep45360.

[7] R. Ramakrishnaiah *et al.*, "Preliminary fabrication and characterization of electron beam melted Ti–6Al–4V customized dental implant," *Saudi J Biol Sci*, vol. 24, no. 4, pp. 787–796, May 2017, doi: 10.1016/j.sjbs.2016.05.001.

[8] P. Krakhmalev, G. Fredriksson, I. Yadroitsava, N. Kazantseva, A. du Plessis, and I. Yadroitsev, "Deformation Behavior and Microstructure of Ti6Al4V Manufactured by SLM," *Phys Procedia*, vol. 83, pp. 778–788, 2016, doi: 10.1016/j.phpro.2016.08.080.

[9] H. Zhang, Y. Zhao, S. Huang, S. Zhu, F. Wang, and D. Li, "Manufacturing and Analysis of High-Performance Refractory High-Entropy Alloy via Selective Laser Melting (SLM)," *Materials*, vol. 12, no. 5, p. 720, Mar. 2019, doi: 10.3390/ma12050720.

[10] A. Aimar, A. Palermo, and B. Innocenti, "The Role of 3D Printing in Medical Applications: A State of the Art," *J Healthc Eng*, vol. 2019, pp. 1–10, Mar. 2019, doi: 10.1155/2019/5340616.

[11] M.-H. Hong, B. Min, and T.-Y. Kwon, "Fabricating High-Quality 3D-Printed Alloys for Dental Applications," *Applied Sciences*, vol. 7, no. 7, p. 710, Jul. 2017, doi: 10.3390/app7070710.

[12] J. P. M. TRIBST, A. M. de O. D. PIVA, A. L. S. BORGES, and M. A. BOTTINO, "Influence of crown and hybrid abutment ceramic materials on the stress distribution of implant-supported prosthesis," *Rev Odontol UNESP*, vol. 47, no. 3, pp. 149–154, Jun. 2018, doi: 10.1590/1807-2577.04218.

[13] W. Semper-Hogg, S. Kraft, S. Stiller, J. Mehrhof, and K. Nelson, "Analytical and experimental position stability of the abutment in different dental implant systems with a conical implant–abutment connection," *Clin Oral Investig*, vol. 17, no. 3, pp. 1017–1023, Apr. 2013, doi: 10.1007/s00784-012-0786-1.

[14] P. Balamurugan and N. Selvakumar, "Development of patient specific dental implant using 3D printing," *J Ambient Intell Humaniz Comput*, vol. 12, no. 3, pp. 3549–3558, Mar. 2021, doi: 10.1007/s12652-020-02758-6.

[15] D. Jörn, P. Kohorst, S. Besdo, M. Rücker, M. Stiesch, and L. Borchers, "Influence of lubricant on screw preload and stresses in a finite element model for a dental implant," *J Prosthet Dent*, vol. 112, no. 2, pp. 340–348, Aug. 2014, doi: 10.1016/j.prosdent.2013.10.016.

[16] M. A. Atieh, N. Alsabeeha, and W. J. Duncan, "Stability of tapered and parallel-walled dental implants: A systematic review and meta-analysis," *Clin Implant Dent Relat Res*, vol. 20, no. 4, pp. 634–645, Aug. 2018, doi: 10.1111/cid.12623.

[17] M. Sarraf, E. Rezvani Ghomi, S. Alipour, S. Ramakrishna, and N. Liana Sukiman, "A state-of-the-art review of the fabrication and characteristics of titanium and its alloys for biomedical applications," *Biodes Manuf*, vol. 5, no. 2, pp. 371–395, Apr. 2022, doi: 10.1007/s42242-021-00170-3.

[18] S. K. Mishra, R. Chowdhary, B. R. Chrcanovic, and P. Brånemark, "Osseoperception in Dental Implants: A Systematic Review," *Journal of Prosthodontics*, vol. 25, no. 3, pp. 185–195, Apr. 2016, doi: 10.1111/jopr.12310.

[19] Z. Liu, B. He, T. Lyu, and Y. Zou, "A Review on Additive Manufacturing of Titanium Alloys for Aerospace Applications: Directed Energy Deposition and Beyond Ti-6Al-4V," *JOM*, vol. 73, no. 6, pp. 1804–1818, Jun. 2021, doi: 10.1007/s11837-021-04670-6.

[20] Z.-S. Gao *et al.*, "Research on gear tooth forming control in the closed die hot forging of spiral bevel gear," *The International Journal of Advanced Manufacturing Technology*, vol. 94, no. 5–8, pp. 2993–3004, Feb. 2018, doi: 10.1007/s00170-017-1116-1.

[21] C. K. Chua, K. F. Leong, and J. An, "Introduction to rapid prototyping of biomaterials," in *Rapid Prototyping of Biomaterials*, Elsevier, 2020, pp. 1–15. doi: 10.1016/B978-0-08-102663-2.00001-0.

[22] N. Zilberman, Y. Audzevich, G. Kalogeridou, N. Manihatty-Bojan, J. Zhang, and A. Moore, "NetFPGA," in *Proceedings of the 2015 ACM Conference on Special Interest Group on Data Communication*, New York, NY, USA: ACM, Aug. 2015, pp. 363–364. doi: 10.1145/2785956.2790029.

[23] J. Feng, J. Fu, X. Yao, and Y. He, "Triply periodic minimal surface (TPMS) porous structures: from multi-scale design, precise additive manufacturing to multidisciplinary applications," *International Journal of Extreme Manufacturing*, vol. 4, no. 2, p. 022001, Jun. 2022, doi: 10.1088/2631-7990/ac5be6.

[24] J. Jung, S. Hong, S. Yoon, J. Kim, and J. Heo, "Automated 3D Wireframe Modeling of Indoor Structures from Point Clouds Using Constrained Least-Squares Adjustment for As-Built BIM," *Journal of Computing in Civil Engineering*, vol. 30, no. 4, Jul. 2016, doi: 10.1061/(ASCE)CP.1943-5487.0000556.

[25] Z. Fan *et al.*, "3D Printing of Porous Nitrogen-Doped Ti_3C_2 MXene Scaffolds for High-Performance Sodium-Ion Hybrid Capacitors," *ACS Nano*, vol. 14, no. 1, pp. 867–876, Jan. 2020, doi: 10.1021/acsnano.9b08030.

[26] J. Schweiger, D. Edelhoff, and J.-F. Güth, "3D Printing in Digital Prosthetic Dentistry: An Overview of Recent Developments in Additive Manufacturing," *J Clin Med*, vol. 10, no. 9, p. 2010, May 2021, doi: 10.3390/jcm10092010.

[27] F. Jasinski, P. B. Zetterlund, A. M. Braun, and A. Chemtob, "Photopolymerization in dispersed systems," *Prog Polym Sci*, vol. 84, pp. 47–88, Sep. 2018, doi: 10.1016/j.progpolymsci.2018.06.006.

[28] B. Msallem, N. Sharma, S. Cao, F. S. Halbeisen, H.-F. Zeilhofer, and F. M. Thieringer, "Evaluation of the Dimensional Accuracy of 3D-Printed Anatomical Mandibular Models Using FFF, SLA, SLS, MJ, and BJ Printing Technology," *J Clin Med*, vol. 9, no. 3, p. 817, Mar. 2020, doi: 10.3390/jcm9030817.

[29] T. Rehbein, M. Johlitz, A. Lion, K. Sekmen, and A. Constantinescu, "Temperature- and degree of cure-dependent viscoelastic properties of photopolymer resins used in digital light processing," *Progress in Additive Manufacturing*, vol. 6, no. 4, pp. 743–756, Dec. 2021, doi: 10.1007/s40964-021-00194-2.

[30] Md. A. Ali, C. Hu, E. A. Yttri, and R. Panat, "Recent Advances in 3D Printing of Biomedical Sensing Devices," *Adv Funct Mater*, vol. 32, no. 9, Feb. 2022, doi: 10.1002/adfm.202107671.

[31] J. Fiocchi, A. Tuissi, and C. A. Biffi, "Heat treatment of aluminium alloys produced by laser powder bed fusion: A review," *Mater Des*, vol. 204, p. 109651, Jun. 2021, doi: 10.1016/j.matdes.2021.109651.

[32] A. Nouri, A. Rohani Shirvan, Y. Li, and C. Wen, "Additive manufacturing of metallic and polymeric load-bearing biomaterials using laser powder bed fusion: A review," *J Mater Sci Technol*, vol. 94, pp. 196–215, Dec. 2021, doi: 10.1016/j.jmst.2021.03.058.

[33] T. Scalici, V. Fiore, and A. Valenza, "Experimental assessment of the shield-to-salt-fog properties of basalt and glass fiber reinforced composites in cork core sandwich panels applications," *Compos B Eng*, vol. 144, pp. 29–36, Jul. 2018, doi: 10.1016/j.compositesb.2018.02.021.

[34] D. Ye, G. S. Hong, Y. Zhang, K. Zhu, and J. Y. H. Fuh, "Defect detection in selective laser

melting technology by acoustic signals with deep belief networks," *The International Journal of Advanced Manufacturing Technology*, vol. 96, no. 5–8, pp. 2791–2801, May 2018, doi: 10.1007/s00170-018-1728-0.

[35] C. Wang, X. P. Tan, S. B. Tor, and C. S. Lim, "Machine learning in additive manufacturing: State-of-the-art and perspectives," *Addit Manuf*, vol. 36, p. 101538, Dec. 2020, doi: 10.1016/j.addma.2020.101538.

[36] D. G. K. Hong and J. Oh, "Recent advances in dental implants," *Maxillofac Plast Reconstr Surg*, vol. 39, no. 1, p. 33, Dec. 2017, doi: 10.1186/s40902-017-0132-2.

[37] S. A. Khairallah *et al.*, "Controlling interdependent meso-nanosecond dynamics and defect generation in metal 3D printing," *Science (1979)*, vol. 368, no. 6491, pp. 660–665, May 2020, doi: 10.1126/science.aay7830.

[38] X. Wang, M. Jiang, Z. Zhou, J. Gou, and D. Hui, "3D printing of polymer matrix composites: A review and prospective," *Compos B Eng*, vol. 110, pp. 442–458, Feb. 2017, doi: 10.1016/j.compositesb.2016.11.034.

[39] P. Bajaj, A. Hariharan, A. Kini, P. Kürnsteiner, D. Raabe, and E. A. Jägle, "Steels in additive manufacturing: A review of their microstructure and properties," *Materials Science and Engineering: A*, vol. 772, p. 138633, Jan. 2020, doi: 10.1016/j.msea.2019.138633.

[40] N. A. Chartrain, C. B. Williams, and A. R. Whittington, "A review on fabricating tissue scaffolds using vat photopolymerization," *Acta Biomater*, vol. 74, pp. 90–111, Jul. 2018, doi: 10.1016/j.actbio.2018.05.010.

[41] M. Mehrpouya, D. Tuma, T. Vaneker, M. Afrasiabi, M. Bambach, and I. Gibson, "Multimaterial powder bed fusion techniques," *Rapid Prototyp J*, vol. 28, no. 11, pp. 1–19, Dec. 2022, doi: 10.1108/RPJ-01-2022-0014.

[42] S. F. S. Shirazi *et al.*, "A review on powder-based additive manufacturing for tissue engineering: selective laser sintering and inkjet 3D printing," *Sci Technol Adv Mater*, vol. 16, no. 3, p. 033502, Jun. 2015, doi: 10.1088/1468-6996/16/3/033502.

[43] E. Liverani, S. Toschi, L. Ceschini, and A. Fortunato, "Effect of selective laser melting (SLM) process parameters on microstructure and mechanical properties of 316L austenitic stainless steel," *J Mater Process Technol*, vol. 249, pp. 255–263, Nov. 2017, doi: 10.1016/j.jmatprotec.2017.05.042.

[44] E. Lahtinen, R. L. M. Precker, M. Lahtinen, E. Hey-Hawkins, and M. Haukka, "Selective Laser Sintering of Metal-Organic Frameworks: Production of Highly Porous Filters by 3D Printing onto a Polymeric Matrix," *Chempluschem*, vol. 84, no. 2, pp. 222–225, Feb. 2019, doi: 10.1002/cplu.201900081.

[45] C. Zhong, N. Pirch, A. Gasser, R. Poprawe, and J. Schleifenbaum, "The Influence of the Powder Stream on High-Deposition-Rate Laser Metal Deposition with Inconel 718," *Metals (Basel)*, vol. 7, no. 10, p. 443, Oct. 2017, doi: 10.3390/met7100443.

[46] A. Bonsall and S. Rajpara, "A review of the quality of life following pulsed dye laser treatment for erythemotelangiectatic rosacea," *Journal of Cosmetic and Laser Therapy*, vol. 18, no. 2, pp. 86–90, Feb. 2016, doi: 10.3109/14764172.2015.1063663.

[47] T. Pasang *et al.*, "Directionally-Dependent Mechanical Properties of Ti6Al4V Manufactured by Electron Beam Melting (EBM) and Selective Laser Melting (SLM)," *Materials*, vol. 14, no. 13, p. 3603, Jun. 2021, doi: 10.3390/ma14133603.

[48] S. Tammas-Williams, P. J. Withers, I. Todd, and P. B. Prangnell, "The Effectiveness of Hot Isostatic Pressing for Closing Porosity in Titanium Parts Manufactured by Selective Electron Beam Melting," *Metallurgical and Materials Transactions A*, vol. 47, no. 5, pp. 1939–1946, May 2016, doi: 10.1007/s11661-016-3429-3.

[49] A. Reichardt *et al.*, "Advances in additive manufacturing of metal-based functionally graded materials," *International Materials Reviews*, vol. 66, no. 1, pp. 1–29, Jan. 2021, doi: 10.1080/09506608.2019.1709354.

[50] S. Pillai *et al.*, "Dental 3D-Printing: Transferring Art from the Laboratories to the Clinics," *Polymers (Basel)*, vol. 13, no. 1, p. 157, Jan. 2021, doi: 10.3390/polym13010157.

[51] K. Pałka and R. Pokrowiecki, "Porous Titanium Implants: A Review," *Adv Eng Mater*, vol. 20, no. 5, May 2018, doi: 10.1002/adem.201700648.

[52] A. Brizuela *et al.*, "Influence of the Elastic Modulus on the Osseointegration of Dental Implants," *Materials*, vol. 12, no. 6, p. 980, Mar. 2019, doi: 10.3390/ma12060980.

[53] S. M. H. Hojjatzadeh *et al.*, "Pore elimination mechanisms during 3D printing of metals," *Nat Commun*, vol. 10, no. 1, p. 3088, Jul. 2019, doi: 10.1038/s41467-019-10973-9.

[54] T. Borges, T. Lima, Á. Carvalho, C. Dourado, and V. Carvalho, "The influence of customized abutments and custom metal abutments on the presence of the interproximal papilla at implants inserted in single-unit gaps: a 1-year prospective clinical study," *Clin Oral Implants Res*, vol. 25, no. 11, pp. 1222–1227, Nov. 2014, doi: 10.1111/clr.12257.

[55] M. A. Atieh, N. Alsabeeha, and W. J. Duncan, "Stability of tapered and parallel-walled dental implants: A systematic review and meta-analysis," *Clin Implant Dent Relat Res*, vol. 20, no. 4, pp. 634–645, Aug. 2018, doi: 10.1111/cid.12623.

[56] O. Geckili, H. Bilhan, E. Geckili, A. Cilingir, E. Mumcu, and C. Bural, "Evaluation of Possible Prognostic Factors for the Success, Survival, and Failure of Dental Implants," *Implant Dent*, vol. 23, no. 1, pp. 44–50, Feb. 2014, doi: 10.1097/ID.0b013e3182a5d430.

[57] S. M. Balaji, "Maxillofacial Surgery and Artificial Intelligence," *Ann Maxillofac Surg*, vol. 13, no. 1, pp. 1–2, 2023, doi: 10.4103/ams.ams_86_23.

[58] G.-B. Menchini-Fabris, U. Covani, G. Crespi, P. Toti, B. Brevi, and R. Crespi, "Customized vs Conventional Implant-Supported Immediate Provisional Crowns for Fresh-Socket Implant: A Medium-Term Cone Beam Computed Tomography Study," *Int J Oral Maxillofac Implants*, vol. 34, no. 6, pp. 1505–1511, Nov. 2019, doi: 10.11607/jomi.7199.