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REVIEW ARTICLE - MEDICAL TECHNIQUES

Subtractive and Additive Technologies in Fixed Dental Restoration: A Systematic Review

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Abstract

Today, computers and digital devices are an indispensable part of our daily lives, and dentistry is no exception. Dentistry has adopted a number of digital technologies, including CAD/CAM (computer-aided design and manufacturing) systems. The goal of the current study is to evaluate the current state of knowledge on dental alloy manufacturing using subtractive and additive techniques for metal ceramic restoration. On this topic, an electronic systematic review was conducted in various databases (Science Direct, PubMed, Web of Science, and Google Scholar searches), as well as a hand search of the scientific literature. Published work was collected, analyzed, and relevant articles were chosen for inclusion in this review from 2008 to 2021. The online databases were searched for articles published that appeared between 2008 and 2021, with no time or language constraints we grouped relevant search terms together, such as "Computer-Aided Design, CAD/CAM, dentistry, dental fabrication, restoration, additive manufacturing." We recognized publications individually and systematically screened titles, summaries, and complete texts of the obtained publications. The findings indicate that current knowledge is sufficient to recommend subtractive manufacturing for crowns and fixed dental restorations for routine clinical use, with improvements in each of the current metal-ceramic veneering materials and procedures. According to the review, several digital technologies, such as systems of computer aided design and aided manufacturing were used in different dental specialties. Application of CAD/CAM technology provided numerous benefits while posing few limitations.

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1. Introduction

Fixed dental prosthesis was complicated, and it was strongly influenced via technician and operator company factors, resulting in low production numbers. Techniques advancements with (CAD/CAM) technologies have been developed for rapid produced of fixed restorations, thereby eliminating the disadvantages of the traditional casting method [1, 2]. Structures can be built using either a CAD/CAM program based on the milling of prefabricated blocks or based on material layer by layer. The CAD/CAM system was made up of three main components: a scanner (digitalization tool), which scans digital data to be processed by the computer. CAD software is used to create a set of data about the product to be fabricated and to design the prosthesis. Furthermore, production technology employs processing machines or equipment that converts data into the desired product and produces restoration [3]. CAD/CAM systems are classified based on their location; in the dental field, they are dental clinic CAD/CAM systems, laboratory CAD/CAM systems, and centralized fabrication [4]. A CAD/CAM system is regarded as a cost-effective, reproducible, and applicable method for creating unique models [5]. Because of it gained the trust of the profession and the patients. Today, increased technology advancements like additive manufacturing made it possible to mass produce products with unique designs in only one production step. This technique has greatly benefitted dentistry, particularly in the production of permanent dental restorations [6].

The sub additive manufacturing technologies enable mass manufacturing for better quality, individualized dental restorations, avoiding outsourcing of labor-intensive and operator-dependent processes, lowering manufacturing costs, decreasing patient wait times, and lowering the possibility of manufacturing-related human error [7].

The additive manufacturing permit the large manufacture of higher quality personalized dental restorations, prevent the outsourcing of labor-intensive and operating company processes, cut down on manufacturing costs, patient wait times, and the possibility of human mistake during production. Sub additive technology can be used to produced metal substrate in restorative dentistry [7]. AM is defined by the American Society for Testing and Materials (ASTM) as "techniques of combining materials to design items from 3D model data, often layer by layer, as contrasted with subtractive approaches." and identified seven kinds of AM: material extrusion, stereo lithography (SLA) method, material jetting process, powder bed fusion (PBF) process, sheet lamination, binder jetting, and direct energy deposition [8]. In addition it involves the following procedures: the processes of selective laser sintering (SLS), selective laser melting (SLM), and electron beam melting (EBM) [7].

Nomenclature & Symbols			
3D printer	Three-Dimensional Printer	AM	Additive Manufacturing
PFM	Porcelain Fused to Metal	FDPs	Fixed Dental Prosthesis
ASTM	American Society for Testing and Materials		

The purpose of this review was to gather data on the CAD/CAM subtractive and AM technologies that are currently employed to create fixed dental prostheses.

2. Procedures and Materials

Google Scholar, PubMed, Science Direct, and Z-library electronic databases were searched for CAD/CAM milling techniques and additive manufacturing techniques. The criteria for inclusion were research articles published between 2008 and 2022. The purpose of this review was to provide a scientific and practical overview of additive manufacturing processes and CAD/CAM systems. In this review, summarized the categorization and characteristics of these technologies that were used in dentistry. Based on the technology's first component. In addition to studying the existing literature on various manufacturing techniques, the current work attempts to present research challenges and future directions. The current study's findings will be useful in all areas of dentistry practice.

3. Subtractive Manufacturing

Material was subtracted from a block using the subtractive method to leave the desired shaped part (the restoration). Subtractive fabrication can effectively create complete shapes, but at the expense of material waste. A typical dental restoration requires the removal of approximately 90% of a prefabricated block [9].

3.1. Advantages and disadvantages of CAD/CAM technology

Several benefit for application dental restorations by CAD/CAM technology over conventional techniques. Some benefit digital scans have the potential to be quicker and easier than traditional impressions, which speeds up design and production as well. A full-contour crown can be milled in only six minutes, for example, thanks to the elimination of casting, wax pattern, investment, and burnout [10, 11]. Patients no longer need temporary restorations, which take time to create and fit. The accuracy of measurements and fabrication results in extremely high-quality CAD/CAM restorations. These systems have a natural appearance since the ceramic blocks have a translucent quality that resembles enamel and are offered in a range of hues.

Lastly, consistency in quality was achieved by the absence of internal faults in prefabricated ceramic blocks and the creation of wear-resistant shapes by the software program. Reduced time, labor savings, and patients should be attracted by the promise of quicker, higher-quality restorations[10]. Additionally, eliminate impressions that make patient gag. Another advantages was that all scans may be saved on the computer, as opposed to typical stone models, which take up space and can crack or chip if not stored properly [10, 12]. however, there were some drawbacks to CAD/CAM systems. The expert must spend time and money on training in addition to the initial cost of the tools and software. The completion line must be clearly visible in the scan, and the neighbouring teeth with occlusal must be precisely replicated. Soft-tissue management, retraction, and moisture control were necessary for digital scanning just like importance for traditional imprints [10].

3.2. Additive manufacturing (AM) technologies mechanisms and principles

Sub additive manufacturing (AM) techniques were divided into seven classification by the ASTM [13]. Summary of the AM classification, as shown in the Table 1. The current sub additive techniques for fabricated metal substrate for frameworks were primarily based on (PBF)

Table 1. Summarization of the additive manufacturing (AM) classification [14]

Additive Manufacturing Processes	Material Form	Types of Material	Name of Technologies
Vat photo polymerization (VPP)	Liquid	Resin	(DLP) (SLA)
Powder bed fusion (PBF)	Powder	Ceramic Metal Plastic	(DMLS) (SLM) (SLS)
Material extrusion (MEX)	Filament, pellets, paste	Ceramic Metal Plastic	(FDM), (FFF)
Binder jetting BJ	Powder	Ceramic Metal Plastic	(CJP)
Directed energy deposition (DED)	powder, wire	Metal	(LENS)
Sheet lamination (SL)	Sheets	Metal plastic	(LOM)
Material jetting (MJT)	Liquid	Plastic	(PolyJet)

3.3. Advantage of AM technologies [15]

There were several advantages for using AM technology in the fabrication process include:

- Fabricated less waste: methods by subtractive techniques could remove up to 90% of the starting material. AM processes, use only a small material than is required in the final form, with the excess being utilized for supporting structures.

- Even more money could be saved if several parts were consolidated into one. Because metal did not chopped as it passes through a manufacturing plant, additive manufacturing used less energy than subtractive procedures.
- Extend device life: It was frequently difficult to find replacement parts for older manufacturing equipment. This was due to the fact that manufacturers update their products and discontinue providing replacement parts for older models. Simply "print," finish, and install a copy of the part if a CAD model was available or could be created.
- Reduce the amount of time that take to complete repairs by ordering replacement parts in advance. When a machine was down, production could potentially stop or more expensive manufacturing techniques may need to be used.

3.4. Disadvantage of AM technologies [16]

There were several disadvantages to use AM technology in the fabrication process include:

- Limited resources
- Build Size Restrictions
- Post-production.
- Massive Volumes
- Parts Organization.
- Job losses in manufacturing.
- Inaccuracies in design

3.5. Additive manufacturing processes powder bed fusion (PBF)

Powder Bed Fusion techniques were some of the first products to come onto the market. Selective Laser Sintering, developed at the University of Texas at Austin in the United States, was the first PBF procedure to be commercialized, and it works well with polymers, metals, ceramics, and composites to a lesser extent. There were more and more machine options for fusing substances with various types of energy [17]. In order to create 3D parts, PBF processing is defined by the ASTM standard as the layer-by-layer melting of specific areas of a thin, flat powder bed (20-100 µm thick) in accordance with input CAD geometry. Given its attractive ability to create complicated geometries utilizing a variety of materials, powder bed fusion techniques were one of the most popular additive manufacturing (AM) technologies [18].

3.6. General classification of powder bed fusion (PBF)

There were four primary PBF techniques these technologies' had different abilities in their energy sources and powder materials [19]:

- Thermal fused (selective heat sintering)
- Electron beam fused (electron beam melting)
- Energy fused (multi jet fusion)
- Laser fused

3.6.1. Selective laser sintering

Carl Deckard developed the SLS process in the mid-1980s, and it was patented in 1989 [20]. Energy source by high laser power was used in the SLS process to selectively sinter the powdered material, during the sintering process the heat treatment has been applied to the material, at temperatures below their melting points, the powders were transformed into coherent solids. [21, 22]. In contrast to the DMLS, SLM, and EBM, which were used exclusively to produce metals and alloys, the SLS was generally utilized to process polymers and ceramics[23]. However, SLS had significant limitations, such as porosity of the product and the manufacturing time necessary owing to the printer's required heating time and the 3D object's required cooling time [23]. As shown in Fig.1.

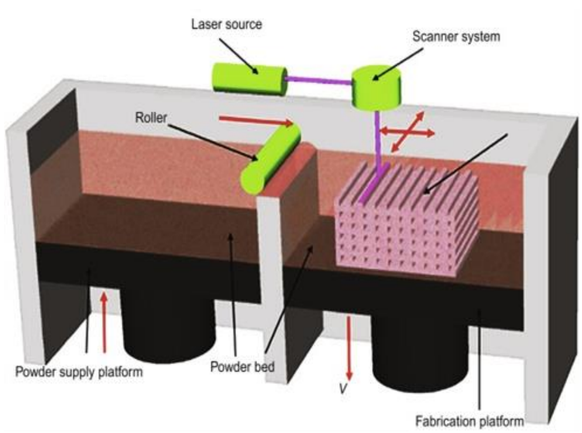

Fig. 1. Selective laser sintering [24]

3.6.2. Direct metal laser sintering (DMLS)

DMLS has been commercially available since 1995 [25], DMLS in a PBF process, metal powders were sintering into the final subject component using the prescribed metal powder and high laser power. DMLS was a continuation of the SLS method conceptually speaking, was the same process. It regenerates three-dimensional components from layer-upon-layer additions of fused metal powder using alloys made of steel, nickel, cobalt, titanium, and titanium [19, 26], as shown in Fig. 2.

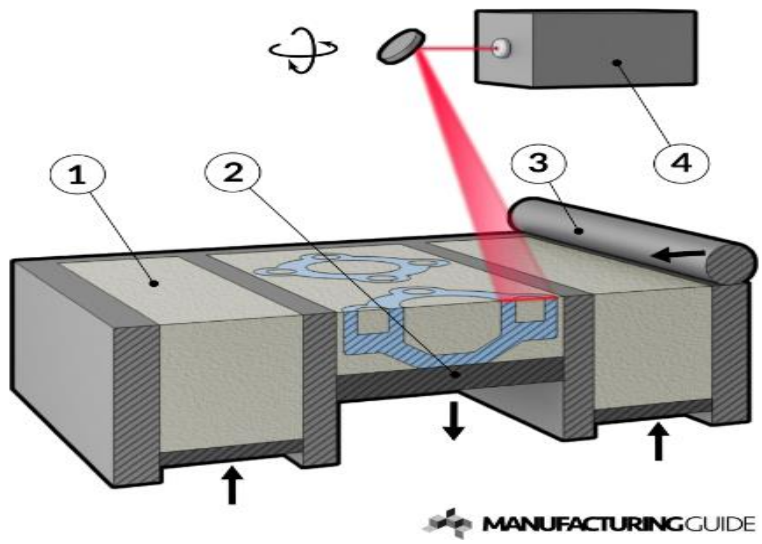

Fig. 2. Direct metal laser sintering (DMLS) [27]

3.6.3. Selective laser melting (SLM)

MCP tooling technologies (United Kingdom) commercialized the SLM in 2005, to strong and high-performance lasers. The SLM procedure was comparable to selective laser sintering in that powder was melted entirely rather than partially [28, 29]. In general, selective laser melting can fabricated strong and dense parts, whereas SLM was better suited for porous and weak objects[30]. The development of SLM laser systems began with CO2 lasers (10.6 m). This was because metallic powders absorb more infrared radiation at these wavelengths than other materials [31]. SLM technology, was widely used to create high-performance metallic components, including high-performance heat exchangers, stronger, more affordable, and long-lasting inductors[32]. The primary benefit of SLM was its capacity to manufacture intricate metal part topologies with high spatial accuracy at a reasonable price. This makes it possible to quickly incorporate new, topology-optimized components (with decreased weight, cooling channels, decreased inertia, enhanced heat exchange, etc) (new injection molded parts, jigs, tools, staff training, and so on)[33], as shown in Fig. 3.

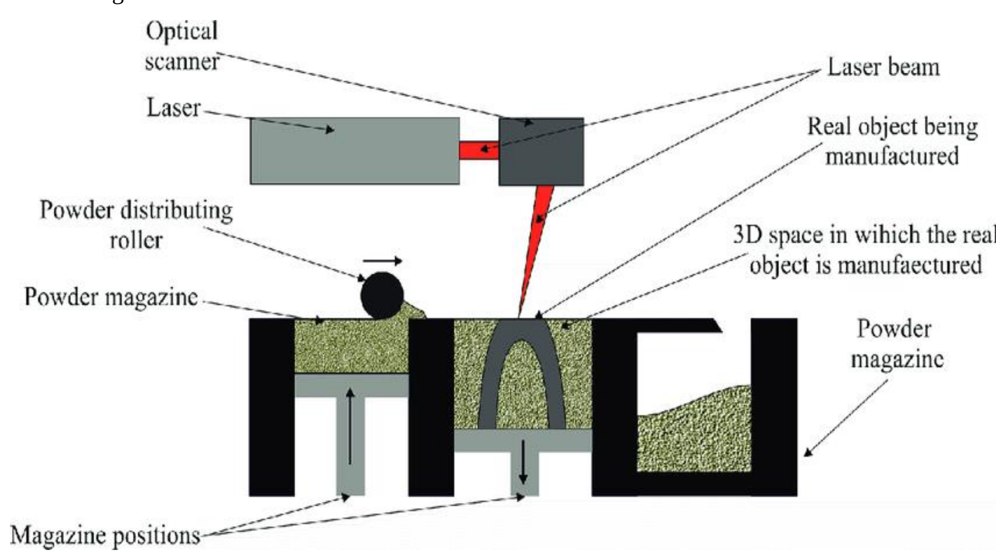

Fig. 3. Selective laser melting (SLM) [34]

4. Discussion

Computer assisted design-computer aided manufacturing dominating the restoration industry, these methods such as laser melting and CNC machining, combine subtractive and additive manufacturing for the production of CoCr, and the fit and quality of these repairs must be assessed [35]. Summarization of current review technological advances in CAD/CAM and additive technologies, the primary goal of this review was to examine the use of subtractive and additive technologies in fixed dental restoration, with an emphasis on the manufacturing of metallic FDP frames for the dentistry sector.

There were numerous advantages to use CAD/CAM technology in the manufacturing techniques [36], using innovative materials, being more economical, and tightening up quality control, and labour reduction. The effectiveness of quality management was increased by standardizing production processes for dental prosthetics. Dental labs became computerized manufacturing hubs as a result of CAD/CAM technology's increased productivity and improved quality control. Titanium and ceramics were two examples of innovative materials that could be applied with high performance accuracy because to CAD/CAM by boosting productivity, CAD/CAM improved dental prosthetic production's capacity to compete, sustaining market share in high-wage nations [3]. The AM processes with particular attention paid to the dentistry industry's production of metallic FDP frameworks. This method less complex than lost wax casting. The CAD-CAM specialist, on the other hand, must be knowledgeable, in order to select the appropriate process parameters and post processing methods, without it, the final output might not be appropriate for usage in real-world situations [37]. The absence of standards or guidelines guiding the manufacturing of starting powder ingredients leads to heterogeneities and is one of the current drawbacks of AM technology [38]. This leads to melt pool instabilities, which affect the dental object's quality. Another constraint has to do with logistics, and safety. Due to their high combustibility, some metal powders, particularly titanium powder, must be handled and stored with extreme caution [39]. Additionally, the use of SLS and associated AM technologies requires specialized training for dental technicians [40]. Furthermore, because of the use of laser or electron beams, AM technology consumes significantly more energy than traditional manufacturing for a single restoration [41].

5. Conclusions

Several digital technologies, such as CAD/CAM systems for producing prostheses with machines and computers have been introduced to the dental field.

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