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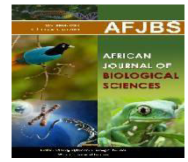

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Implant overdenture framework construction techniques: A review of conventional casting, milling and additive techniques

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Abstract:Background: The introduction of implant overdentures has overcome problems of speaking, loss of retention, inefficient mastication and decreased patient satisfaction convoyed with conventional complete dentures. Several techniques are employed in implant frameworks construction; conventional casting, milling and additive manufacturing. Due to conventional casting dimensional imprecision, CAD-CAM construction techniques have been widely utilized in the dental field in an attempt to address the shortcomings of previous construction technique. Although milling technique entails superior construction accuracy, yet its high cost and difficulties faced in tiny details production are considered limitations. Additive manufacturing techniques have been used for their reasonable price and the ability of fine details production. Selective laser melting is one of the promising additive manufacture's methods that has been employed in metal frameworks fabrication as cobalt chromium and titanium alloys. This review provides an overview of both traditional and CAD-CAM construction techniques, including milling and additive manufacturing, outlining their manufacturing processes, advantages, disadvantages, and potential materials of use

Keywords: Additive manufacturing, Implant overdenture frameworks, Milling, Conventional casting, Cobalt chromium

Introduction

Implant-retained overdentures are quite popular treatment modality for edentulous mandible, since the cost is reasonable cost and they require fewer implants number thus reducing the need for extensive surgery.

Additionally, they simplify the hygienic procedures for the patient by enabling them to remove and clean them themselves, enhance speech and lip support, and maintain aesthetics by permitting tooth alignment independent of implant location.[1]

Many studies in the literature [2-7] had discussed the clinical performance of implant retained mandibular overdenture as a satisfactory treatment modality for edentulous jaw. Investigations have reported improved retentive features of implant supported prosthesis compared to conventional complete dentures and its relation with increased stability with subsequent higher patient satisfaction.[2]

In addition, a systematic review had evaluated masticatory efficiency and biting force in patients rehabilitated with implant retained mandibular overdenture, results showed enhanced chewing ability increased maximum biting force with overall enhanced patient satisfaction.[3,6]

Furthermore, regarding speech; implant retained overdenture resulted in improvement in patient phonation within time especially at 3 months follow up after delivery.[4] Besides, implant retained overdenture prostheses have been related to low rate of marginal bone loss for the first 10 years with no further bone loss recorded thereafter.[5]

Also, in a systematic review comparing implant retained prostheses and complete dentures as edentulism treatment modalities, patients who have implant retained prostheses report higher levels of satisfaction overall, masticatory performance, comfort, chewing ability, and oral health quality of life.[6,7]

In the dental industry, a wide range of construction techniques, such as conventional casting, milling, and additive, together with a variety of materials, are available for the manufacturing of implant frameworks.[8,9]

I- Conventional casting technique:

Commonly, the lost wax technique had been employed in metal frameworks fabrication which were at first composed of gold alloys. However due to the high cost of gold alloy, substitute metals like titanium, cobalt chromium, and silver palladium alloys were used instead.[10]

specific alloys are needed to meet the conventional casting requirements, casting technique entails melting of the metal ingot followed by further cooling according to the metal framework shape, consequently the liquefied metal would unavoidably shrink. More contraction takes place when the solidifying temperature rises. Accurately fabricating full-arch frames utilising Co-Cr alloys in traditional techniques is challenging due to an intrinsic property of the casting procedure. Thus, appropriate investment material is advised to offset this shrinkage.[11-13]

Larger frame sizes with higher alloy contraction and misfit percentages could make this issue quite serious. In order to address misfit issues, the framework should be divided and reassembled; however, this may not address other issues such as alloy inhomogeneity or adaption problems.[14]

Cobalt chromium (Co-Cr) alloy is a pioneer metal in implant overdenture framework fabrication. It is used in conjunction with heat-curable acrylic resin, the purpose of such a blend is to take advantage of material strength and the simplicity with which alterations to the superstructure can be implemented.[15]

Co-Cr is an alloy that is biocompatible, has proper mechanical characteristics, and is reasonably priced. Additionally, it has a high modulus of elasticity, which allows for better stress distribution and provides the material in thin sections with sufficient space for acrylic teeth.[16]

However, the Co-Cr alloy has a high melting point among the various metals, which causes a significant shrinkage and exposes the material to errors and misfits when large frameworks are being constructed.[12]

Subsequently, alternative materials were made available for use in the fabrication of implant overdenture frameworks. One such material was silver palladium, which was mostly chosen over cobalt chrome due to its better fit and affordable price.[17]

Time consumption, complicated laboratory steps, alloy defects and impurities were all additional drawbacks of conventional lost wax technique in implant framework fabrication, hence there was a need for alternative way to overcome these limitations.[18]

II -Digital techniques:

Computer aided design-computer aided manufacturing (CAD-CAM) has become a common method for eliminating earlier fabrication problems in metal frame work construction.CAD-CAM fabrication technique involves two methods: subtractive and additive approches.[19]

Compared to traditional methods, CAD CAM approaches have numerous benefits, such as fewer clinic visits, better denture strength and fit, a reduction in microbial adhesion to prostheses, consistent digital work procedures for clinical research, and Simple denture replication with the digital data that has been stored.[20]

CAD-CAM work has drawbacks such as the high skill level required for impression and vertical dimension of occlusion, jaw relation transfer, lip support maintenance, difficulties defining the mandibular occlusal plane and high laboratory costs.[21]

a- Milling technique:

The foundation of subtractive manufacturing is a computer numerical control (CNC) machine that mills the product out of a block. The CAD design is automatically transferred into the CNC machine's tool path using the CAM software. This includes calculating the direction and amplitude of tool motion as well as sequencing, milling tools, and CNC milling. Because dental restorations vary anatomically, the milling machines mix burs of various sizes. It is demonstrated that the milling precision is within 10 µm.[22]

For metal milling technique, it involves both fully sintered and pre-sintered methods. Fully sintered metals require the block to be hard-cut to the precise dimensions of the framework, which presents issues with tool breakage and machine maintenance.[23]

Although pre-sintered preserves the used tools and machine, it requires more time and money than hard milling since it entails soft cutting the ingot to a size larger than the actual one and then its re-sintering to the soft milled frame.[23]

Various studies have compared some properties between three construction techniques of Co-Cr alloy which are: fully sintered or hard milling, soft milling and conventional casting.[24-26]

In terms of compatibility for a sintered or presintered milled Co-Cr alloy, it showed less iron release than casted Co-Cr, which in turn increased the milled cobalt chrome's biocompatibility.[24] In terms of contraction shrinkage, the fully sintered milled Co-Cr has none, as opposed to conventionally cast and soft milled Co-Cr (10–11%)%.[25] In terms of fit precision, the findings indicated that, when compared to soft milled and laser sintered Co-Cr, fully sintered milled Co-Cr had the lowest vertical misfit.[26]

Later on, titanium alloy has been introduced widely to the markets because of its great fatigue performance, satisfactory mechanical and physical characteristics, affordable price, and biocompatibility. Its high modulus of elasticity made it ideal for usage in vast undercut regions.[27-29]

Since superior aesthetics have become a need to disguise metal reflection of the infra-structure, besides the increase in metal frameworks cost and the notable development in ceramic materials qualities make it possible to use these materials for mouth rehabilitation.[30]

Zircon-oxide ceramic material proved to have aesthetically, biologically and mechanical accepted features since it has high strength property, high wear resistance and better surface qualities with decreased bacterial accumulation.[31-33] Zircon-implant supported prostheses have gained popularity as it enhanced patient psychology and masticatory performance with high survival rate and fewer complications.[34,35]

Polyetheretherketone (PEEK) is a thermoplastic polyaromatic semi-crystalline polymer with a fusion temperature of around 340 °C. It is an inert substance with great biocompatibility and thus advised in people allergic to metals. It also offers good polish ability and reduces plaque formation. Another feature of PEEK is the ability to change its mechanical properties by filling or mixing it with other elements, such as carbonium fibres, which increases the elastic modulus to 18 GPa.[36,37]

PEEK material has a modulus of elasticity that is approximately comparable to bone, resulting in less stress transmission to the abutment and implant. It also has a low specific weight and essentially no wear, making it a trustworthy material for prosthetic rehabilitation.[38,39]

As a disadvantage, deformation of PEEK material under load in implant supported restoration, results showed that PEEK bar is subjected to more deformation when compared to Co-Cr and titanium bar indicating doubtful longevity.[40]

A High-Performance Polymer that is a PEEK modification is called BIOHPP. It has a high physical criterion, compatible, inert material, durable against chemicals and high temperatures (up to 300 degrees) with an elastic modulus that is similar to that of bone. the inherent mechanical quality results from a particular type of ceramic filler that has a small size (0.3-0.5 m), which causes the polymer to be homogeneous. PEKK material, another modified polymer material, has been emphasised as a framework material.[36,41]

Although milling is a precise process, it produces a lot of waste material. It is also not exact in manufacturing undercut areas and complex patterns since ideal precision is dependent on machine axis, accessibility, and the size of the cutting tool bur.[42]

b- Additive techniques:

The additive manufacturing or rapid prototyping used a CAM design and a series of layering techniques to construct 3D objects. According to ASTM Standard, three-dimensional printing methods includes seven categories: powder bed fusion, the binding jetting, material extrusion, directed energy deposition, material jetting, sheet lamination and vat photopolymerization.[43]

Additive manufacturing makes it possible to overcome problems of fine details production of complex structures also helped in decreasing waste material through layering build-up.[44]

A wide range of materials have been employed with additive manufacturing systems; metals like titanium, aluminium, cobalt chrome, molybdenum, and stainless steel; ceramics like zircon and alumina; composites and polymers like polyglycolide, acrylic resin, polylactide, polycaprolactone, and thermoplastic polymers.[45]

Additive manufacturing has been used in the fabrication of dental implants, custom trays, surgical guides, occlusal splints, orthodontic appliances, tissue engineering, prosthetic restorations, dental models and prosthetic frameworks.[46]

Methods of additive manufacturing:

1)-Stereo-lithography:

Also known as the solid-form screen technology, it is mostly utilised to manufacture hard things out of polymers. The polymer powder is laid out in a cross-section using an ultraviolet light beam, and then it is submerged in polymeric resin liquid. The layer is then removed, and another layer is submerged.[47] It has the merit of one-day construction of anatomical diagnostic cast, injecting model, prosthetic moke up and master model for metal casting with high quality and little waste, It’s worthy to mention that this technique is high temperature resistant.[48]

As an adverse aspect, the material itself is week, therefore it requires a supporting material to reinforce it with the consequent of removing it after, which results in expensive machinery costs.[47]

2)-Powder Bed Fusion:

It’s a category of additive manufacturing that entails four subcategories which are: (selective laser sintering, Direct laser melting, selective laser melting and Electron beam melting).[49]

-Selective laser sintering (SLS):

This process is generally composed of three major phases: the warm-up, build, and cooling stages. it utilizes a laser beam (ND-YAG) to sinter the powder of the used material resulting in its partial melting. various materials are used as metals, ceramics, composites and hybrids. This method doesn’t need a supporting material and the former object is with high stiffness and longevity. As a drawback, the 3D formed structure is porous with need for linking agent as cyanoacrylate.[50]

-Fused deposition modelling (FDM):

This approach employs heat to create a three-dimensional object out of thermoplastic material. This method typically employs two different types of material filaments. One is a building substance, while the other is a supporting material. Slicing settings, building orientation, and machine temperature. These are the printing parameters that have the most impact on the mechanical qualities of the finished object. Advantages include quick manufacturing, cost-efficiency, simplicity of access, vast material adaption, and the capacity to make complicated components.

Conversely, it lacks superior surface quality, strength, and the quantity of materials employed. This technique involves a significant use of composites and polymer materials.[51]

-Binder Jetting (PJ):

In this method, layers of either metal powder or sand are applied and bound together with a polymeric binder. Each layer is condensed using a ruler before the next layer is added, and so on, until the entire item is created. benefits include being compatible with almost any powdered material and allowing for contamination-free shaping at room temperature and environment. This method's drawbacks include low resolution, weak layer adhesion, and a complex production procedure.[52]

-Selective laser melting (SLM):

This method utilizes a carbon dioxide laser beam which sinter the material powder resulting in its complete melting thus overcoming the obstacle of porosity, the former object is with high strength and density. The sintered powder is subjected to heat change during production, so a heat retreatment process is required. Nickel- based alloy, Fe alloy, cobalt chrome and Titanium alloys are commonly used with this method.[53]

This effective technology eliminates the need for additional post-processing because to its increased precision and high-quality finishing surface. SLM can reduce manufacturing costs, lead time, and material loss, making it an attractive production technology for important materials and components. It provides design flexibility, adaptability, and eliminates the need for costly tooling compared to conventional fabrication techniques.[54]

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