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Current Concepts and Applications 3d Printable Polymeric Resins in Prosthodontic Restoration: A Comprehensive Review

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ABSTRACT:

Polymeric materials play an important role in the dental domain. Due to the advancements in 3D printing technology in digital work flow, fixed and removable dental prosthesis are fabricated with precise fit. Poly methyl methacrylate, polycarbonate, polyethylene, poly ether- ether ketone, poly urethane, poly ethylene glycol, polypropylene, poly lactic acid, poly di methyl siloxane and acrylonitrile butadiene styrene are the commonly used polymers in restorations. At present 3D printing polymers like poly methyl methacrylate, polylactic acid, acrylonitrile butadiene styrene, polyether ether ketone and poly urethane ethyl acrylate plays a major role in creating dental models, customised special trays, complete removable dentures, fixed crown and bridge framework and removable partial dentures.

Introduction

The term 3D printable polymeric resins in prosthetic restoration refers to the use of polymeric resins that are suitable for 3D printing technology in the field of prosthetic restoration. Prosthetic restoration involves the replacement of missing or impaired oral and maxillofacial structures. In the realm of prosthetic restoration, the integration of 3D printing technology has ushered in a new era of precision and customization. With the advent of 3D printing technology, it has become possible to manufacture prosthetic restoration with greater accuracy and customization. The advent of 3D printing, also known as additive manufacturing, has revolutionized the field by enabling the layer-by-layer construction of prosthetic devices based on digital models.

Polymeric resins are materials that can be formulated into liquid form and then solidify into a desired shape when exposed to specific conditions, such as UV light in the case of photopolymer resins commonly used in stereolithography (SLA) or digital light processing (DLP) 3D printing. 3D printing, also known as additive manufacturing, allows for the layer-by-layer construction of objects based on digital models. One of the main advantages of using 3D printable polymeric resins is the ability to create prosthetic devices that are tailored to the unique anatomy and functional requirements of individual patients. Digital scanning and imaging technologies allow for the creation of accurate 3D models, ensuring a perfect fit and improved comfort for the user.

Prosthetic restoration involves the replacement of missing or impaired oral and maxillofacial structures. Traditional methods often face challenges in achieving a perfect fit and addressing the unique anatomy and functional requirements of individual patients. However, with the integration of 3D printing technology, the landscape has transformed. Digital scanning and imaging technologies allow for the creation of highly accurate 3D

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models, serving as the foundation for the production of customized prosthetic devices.

One of the primary advantages of utilizing 3D printable polymeric resins in prosthetic restoration is the unparalleled precision and customization they offer. The ability to construct prosthetic devices layer by layer based on digital models ensures a perfect fit for each patient. This level of accuracy is especially crucial in oral and maxillofacial applications, where even minor discrepancies can impact functionality and comfort. Dental implants, crowns, bridges, and other prosthetic structures can be precisely tailored to the individual's unique anatomical features, promoting optimal performance and aesthetics. The customization made possible by 3D printing technology extends beyond just anatomical accuracy – it also enhances patient comfort. Prosthetic devices created using 3D printable polymeric resins are designed to match the natural contours of the patient's oral and maxillofacial structures. This results in improved comfort during everyday activities such as speaking and eating. The elimination of ill-fitting prosthetics not only enhances the overall user experience but also contributes to the long-term success and acceptance of prosthetic restoration.

The incorporation of 3D printable polymeric resins in prosthetic restoration represents a significant advancement in the field, offering unprecedented levels of precision, customization, and patient comfort. As technology continues to evolve, the synergy between 3D printing and polymeric resins will likely pave the way for further innovations, ultimately improving the quality of life for individuals in need of prosthetic solutions.

Types of 3D printable polymeric resins

In prosthetic restoration, 3D printing has become a valuable tool, offering customization and precision. Various polymeric resins are used in 3D printing for prosthetic applications, each with distinct properties. Here are some types of 3D printable polymeric resins commonly used in prosthetic restoration

1.Acrylate-Based Resins: Specifically formulated for dental applications, these resins are used for creating dental prosthetics, crowns, bridges, and other dental restorations. Acrylonitrile Butadiene Styrene (ABS) has high strength and makes it suitable for prosthetic restorations with more durability. It is moderately flexible, biocompatible and considered to be safe.

2. Polyurethane-Based Resins: Polyurethane-based resins are known for their flexibility, making them suitable for creating prosthetics that require some degree of elasticity. This is useful in applications like soft tissue prostheses.

3.Polylactic Acid (PLA): PLA is a biodegradable and bioactive thermoplastic derived from renewable resources like corn starch. It is commonly used in prosthetics due to its ease of use and biocompatibility.

4.Polycarbonate (PC) Resins: PC resins are known for their high impact resistance and toughness. These resins are used in prosthetic applications where durability and strength are crucial.

5.Polyethylene (PE) Resins: PE resins are often used for their low friction, good strength, impact resistance, flexibility, biocompactible and wear resistance properties. They may be employed in components of prosthetic devices that require these characteristics.

6.Polyvinyl Alcohol (PVA): PVA is a water-soluble polymer often used as a support material in dual-extrusion 3D printing processes. It helps in printing complex structures and overhangs, and it can be dissolved easily after printing.

7.Photopolymer Resins: These resins cure when exposed to light. They are commonly used in stereolithography (SLA) and digital light processing (DLP) 3D printing technologies. They provide high resolution and smooth surface finishes.

8**.Polyethylene Terephthalate Glycol (PETG):** PETG is a transparent and durable material with good chemical resistance. It may be used in some prosthetic applications where transparency or specific chemical properties are required.

3D printing technologies

1.Stereolithography (SLA): This is one of the earliest 3D printing technologies. SLA uses a laser to solidify liquid resin layer by layer. Polymeric resins suitable for prosthetics are cured with precision, producing highly detailed and accurate models. SLA is known for its ability to create smooth and intricate surfaces, making it suitable for creating realistic prosthetic components.

2.Digital Light Processing (DLP): DLP is similar to SLA but uses a digital light projector to cure the entire layer of resin at once. This can result in faster printing speeds compared to SLA. DLP is also capable of

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producing high-resolution prosthetic components, making it a viable option in the field.

3. Material Jetting: This technology involves jetting tiny droplets of liquid polymer onto a build platform, where they are cured layer by layer. Material jetting can offer a high level of detail and accuracy and allows for the use of multiple materials in a single print. This versatility can be beneficial in creating prosthetic components with varying properties.

4. **PolyJet Printing**: PolyJet is a similar technology to material jetting, where multiple liquid photopolymers are jetted and cured simultaneously. This technology allows for the creation of multi-material and multi-color prosthetic models, enabling the incorporation of different textures and properties within a single print.

5.**Fused Filament Fabrication (FFF) or Fused Deposition Modeling (FDM):** While less common for high-detail prosthetics due to the layer-by-layer nature of the process, FFF/FDM is a widely used 3D printing technology. It involves extruding thermoplastic filament layer by layer to build up the final object. Polymeric resins in filament form can be used in FFF/FDM printers for prosthetic applications.

Advantages

1.3D printing allows for precise customization based on the individual's anatomy, ensuring an optimal fit and improved comfort.

2. Rapid prototyping, reducing the time required for manufacturing and allowing for quicker adjustments and faster rehabilitation of patients.

3.They can accommodate unique anatomical features and providing a more natural appearance.

4. Cost-effectiveness, especially in the production of low-volume, high-complexity dental restorations.

5. Development of specialized polymeric resins suitable for medical applications has expanded the possibilities of 3D printing in healthcare.

6. These materials are often biocompatible, ensuring compatibility with the human body.

7. In prosthetic restoration, the use of advanced polymers enables the creation of lightweight, durable, and comfortable prosthetic devices.

8. 3D printing facilitates the creation of patient-specific anatomical models, aiding surgeons in preoperative planning.

Applications of 3D Printable Polymeric Resins in Prosthodontic restoration

Advancements in 3D printing technology have significantly created an effect in the field of prosthodontic restoration, offering novel solutions for creating various types of prostheses with polymeric resins.

1. Dental Crowns and Bridges: One of the primary applications of 3D printing with polymeric resins in prosthodontics is the fabrication of dental crowns and bridges. Traditional methods often involve multiple steps but by the invent of 3D printing it streamlines the process by creating durable and aesthetically pleasing dental restorations.

2. Dentures and Removable Partial Dentures: 3D printing has revolutionized the production of dentures and removable partial denturesn by using polymeric resins. They helps to fabricate lightweight, comfortable, and precise dentures. The digital nature of 3D printing allows for accurate customization of denture shapes and sizes based on patient alveolar ridges. They also ensures an optimal fit for the edentulous patient.

3. Implant-Supported Prostheses: The use of 3D printable polymeric resins extends to implant-supported prostheses. By leveraging computer-aided design (CAD) and 3D printing technologies, dental professionals can create customized abutments and prosthetic components that seamlessly integrate with the patient's anatomy. This personalized approach enhances the overall success and longevity of implant-supported restorations.

4. Customized Implants: 3D printing allows the creation of customized implants based on the specific anatomy of the patient's maxillofacial region. This is especially beneficial in cases where standard, off-the-shelf solutions may not provide an optimal fit

5.Temporomandibular Joint (TMJ) Prostheses: Polymeric resins in 3D printing playa a significant role in the fabrication of temporomandibular joint prostheses. These prostheses are designed to mimic the natural movement of the jaw, providing relief for patients with TMJ disorders. The ability to tailor the prosthesis to the patient's specific anatomical requirements ensures improved functionality and patient comfort.

6.Patient-Specific Surgical Guides: These 3D printed surgical guides can be created to assist in the precise placement of implants during maxillofacial surgeries. It will enhance accuracy, reduces surgery time, and minimizes potential complications.

7. Anatomical Models for Surgical Planning: By using patient scans 3D printed anatomical models can be prepared for preoperative planning. This can be used by surgeons in order to study the physical model and helps to better understand the patient's unique anatomy, that allows for more informed decisions and also enhance the surgical outcomes.

8. Temporary and Permanent Prostheses: 3D printing enables the fabrication of both temporary and permanent prostheses for maxillofacial defects like orbital, nasal, or auricular prostheses. The digital design and printing process will provide a precise fit and aesthetically pleasing results.

9. Bone Graft Substitutes: 3D printed polymeric resins can be used to create bone graft substitutes or scaffolds that can promote bone regeneration in maxillofacial areas. These structures can also be customized to mimic the patient's bone geometry and also it could encourage natural tissue growth.

10. Aesthetic Facial Reconstruction: 3D Polymeric resins with a range of colours, detailing and textures can be used to create facial prostheses which can closely resemble natural skin, this can provide an aesthetically pleasing appearance for patients undergoing facial reconstruction.

Disadvantages

1. The range of available polymeric resins for 3D printing in dentistry may be limited compared to traditional materials like ceramics or metals. This limitation can affect the ability to match the mechanical and aesthetic properties required for various dental restorations.

2. Some polymeric resins may have issues with long-term biocompatibility. It's crucial for dental materials to be compatible with the oral environment, and the safety of some 3D-printed resins over extended periods may still be a subject of investigation.

3. While there have been significant improvements in the mechanical properties of 3D-printed polymers, they may not yet match the strength and durability of traditional materials. This can be particularly relevant in high-stress areas or for long-term restorations.

4. The post-processing steps required for 3D-printed prosthetics, such as curing and finishing, can be labour-intensive and may require specialized equipment. Achieving the desired surface finish and accuracy might be challenging and time-consuming.

5. The initial investment in 3D printing equipment and materials may be higher compared to traditional methods. Additionally, the cost of resin materials for 3D printing can be relatively expensive, impacting the overall cost-effectiveness for some dental practices.

6. Implementing 3D printing technology in a dental practice requires training and expertise. Dentists and technicians need to familiarize themselves with the technology, software, and specific parameters for successful printing.

7. The build volume of 3D printers can limit the size of prosthetic devices that can be produced in a single print. Additionally, the layer-by-layer additive manufacturing process can be time-consuming, affecting production speed.

8. Achieving uniform post-curing of the printed prosthetics may be challenging. Inconsistent curing can lead to variations in material properties and compromise the final restoration's quality.

Conclusion

The utilization of 3D printable polymeric resins in prosthetic restoration marks a significant advancement in dental technology. The versatility and precision offered by these resins have revolutionized the fabrication of dental prosthetics, providing clinicians with enhanced control over design intricacies and patient-specific customization. The ability to accurately replicate anatomical structures, coupled with the biocompatibility of these resins, ensures optimal patient comfort and function. The efficiency of 3D printing technology in producing intricate prosthetic components has streamlined the restoration process, reducing production time and minimizing material waste. Furthermore, the continual evolution of 3D printing materials and technologies promises even greater possibilities in the field of prosthodontics. As research and development progress, the expansion of available materials and the refinement of printing techniques will likely contribute to improved aesthetics, durability, and overall performance of prosthetic restorations. In light of these advancements, it is evident that 3D printable polymeric resins have become indispensable in modern prosthodontic practice. Their integration not only

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facilitates superior clinical outcomes but also exemplifies the intersection of technology and healthcare, ultimately benefiting both practitioners and patients alike.

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