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Evaluation of Biocompatibility Between Traditional PMMA and 3D Printed Denture Base Polymers. Literature review.

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Abstract

Aim: The aim of this paper is to review the available literature on 3D printed dentures in terms of the used materials and their biocompatibility in comparison with conventional heat-polymerized PMMA resins.

Materials and methods: The research relied on Google Scholar and PubMed publications in English.

Results: Since the technology for printing removable dentures is relatively new, the number of studies on the sensitivity of polymers for printing to microbial adhesion is few. The main goal of all new technologies and materials is to surpass conventional ones in quality but the literature currently presents conflicting opinions regarding the colonization of microorganisms and biofilm formation on the surfaces of 3D-printed dentures. The question of the biocompatibility of the materials used for 3D printed dentures is relevant, as confirmed by the active research of existing materials and the search for new materials with antibacterial properties.

Conclusions: Despite the increasingly widespread use of 3D technologies for the fabrication of removable dentures, some questions remain unresolved and one of them is about materials biocompatibility. Additive manufacturing is becoming an alternative to conventional methods for making removable dentures, but more studies on the biological properties of printing materials are needed to prove their clinical effectiveness.

Keywords: 3D dentures, biocompatibility, biofilm formation

Introduction

Nowadays there is a growing focus on maintaining oral health. The microflora and oral biofilm that develop both on the natural soft and hard tissues in the oral cavity and on the surfaces of dentures are crucial for maintaining good oral and overall health.
Denture stomatitis is a localized or generalized inflammation of the oral mucosa that is in contact with a removable denture. The factors influencing the development of denture stomatitis depend on the individual conditions of each person and the biological qualities of the materials used in prosthetic dentistry. A large part of the oral mucosa is in contact with the denture base, creating favorable conditions for the biofilm formation in the limited space between the mucosa and the denture. On the other hand, the qualities of the material, such as porous structure and surface roughness, can also predispose to colonization on the denture surface.

Aim

The aim of this paper is to review the available literature on 3D printed dentures in terms of the used materials and their biocompatibility in comparison with conventional heat-polymerized PMMA resins.

Materials and Methods

The research relied on Google Scholar and PubMed publications in English.

Results

The oral microflora is an integral part of the overall microbiota of the human body, consisting of over 750 different types of microorganisms. Some of them are free-floating, while others resist the flow of saliva and adhere to enamel, mucosa, or dentures. Adhesion occurs through adhesins on the surface of the cells, leading to the formation of bacterial biofilm (1).
Despite advancements in modern preventive dental medicine and numerous innovations, a significant part of the adult population suffers from partial or complete tooth loss (2). Removable dentures remain a primary treatment method, but a major disadvantage is their colonization by microorganisms and the formation of bacterial biofilm. Since oral health and microbial inhabitants in the oral cavity are crucial to overall health, studying the microbiological qualities of denture materials is important (3).
Introduced for the first time in 1937, polymethyl methacrylate (PMMA) has become the main material used for making dentures. It is characterized by low density, good aesthetic qualities, low cost, easy processing, and relatively good physical and mechanical properties, making it preferred for production of dentures, orthodontic appliances and temporary crowns and bridges (4). Despite the many advantages of PMMA, its susceptibility to microbial colonization remains a major disadvantage (5). Over time, not only does a bacterial biofilm form on it, but microorganisms penetrate deeper layers of the polymer. The oral cavity, in turn, is an ideal microbial incubator due to its moisture, moderate temperature, abundance of nutrients, and combination of soft and hard surfaces (6). There are many diverse microorganisms – bacteria, fungi, and viruses. All of them form a complex ecosystem that affects oral and overall health (7). The nature of the biofilm in patients with dentures is influenced by various factors – individual characteristics (age, overall health) and the denture characteristics (material, manufacturing technology, hygiene, and age).

The biofilm represents a three-dimensional bacterial structure and a separate ecosystem. Initially, all surfaces (natural and artificial) in the oral environment are covered with a pellicule formed by organic and inorganic molecules found in saliva. This layer becomes the basis for biofilm formation because the receptors on the pellicule facilitate the binding with individual microorganisms (primary colonization) within the first few hours. These microorganisms can then bind with other microorganisms (secondary colonization), making microcolony formation possible.

Over time, the microorganisms not only increase in number but also form a tightly attached oral biofilm, serving as a reservoir for agents of numerous infectious diseases (8). If the balance in the ecosystem is disturbed, for example by increasing the quantity of a particular microorganism or compromising immunity, local and systemic defense reactions of the organism are activated. It is known that when an artificial material is introduced into the oral cavity, its surface is quickly colonized by microorganisms. In the presence of dentures, a bacterial biofilm forms on their surface, stimulating local inflammatory processes, most often manifesting as erythema or hyperplasia (9).

Denture stomatitis is a localized or generalized inflammation of the oral mucosa in contact with a removable denture, affecting between 15% and 70% of patients rehabilitated with prosthetic constructions (10). The main etiological factor is considered the presence and increased quantity of Candida albicans, Staphylococcus aureus, and Streptococcus mutans, and their colonization on the oral mucosa and denture surfaces. Other contributing factors include low pH of saliva, increased intake of carbohydrates, various systemic diseases, or certain medications.

Numerous studies demonstrate the connection between Candida albicans adhesion and denture stomatitis (11-14). Representatives of the genus Candida are commonly found and considered harmless members of the human microbiome - Candida albicans, Candida tropicalis, Candida glabrata, Candida parapsilosis, Candida stellatoidae, Candida krusei, Candida kefyr, and others. Approximately 200 species of Candida are known, and 10% of them can cause infections in humans. The most commonly studied is Candida albicans and the other species like C. glabrata, C. famata, C. dubliniensis, and C. tropicalis (15). Of all species, Candida albicans is most frequently isolated from the oral cavity and successfully coaggregates with Streptococcus spp., leading to biofilm formation on saliva-coated surfaces.

It is known that C. albicans, in addition to adhering to oral surfaces, also adheres to acrylic dentures. Local immunity plays a major role in maintaining C. albicans in a commensal state. However, under certain conditions, C. albicans can turn from a harmless commensal into a pathogen for the oral mucosa.

In the last decade, 3D technologies have developed rapidly, allowing the creation of complex and highly precise objects used in various fields, including dental medicine. 3D printing has the potential to modernize and streamline the making of dentures, materials used, and the workflow. An undeniable advantage is the reduction of clinical and laboratory time, quality control, and the reduction of the impact of subjective factors (16,17).

The materials used in 3D printing for denture fabrication are various types of polymers. These polymer chemical compounds differ not only in their physicochemical properties but also in their microbiological properties, necessitating more in-depth research. Since the technology for printing removable dentures is relatively new, the number of studies on the sensitivity of polymers for printing to microbial adhesion is few.

The main goal of all new technologies and materials is to surpass conventional ones in quality. The literature currently presents conflicting opinions regarding the colonization of microorganisms and biofilm formation on the surfaces of 3D-printed dentures.

According to some authors, denture stomatitis is also a problem for printed dentures. Their results show that C. albicans colonization on 3D-printed materials is even higher than on conventional heat-polymerized and milling resins (18, 19). Other authors believe that microbial adhesion to polymers used for denture printing is smaller, and therefore the risk of denture stomatitis is reduced (20, 21).

Meirowitz (19) compared the colonization of Candida by different denture fabrication methods - subtractive, additive, and conventional, including polymers for milling, 3D printing, heat-, and cold polymerization. Adhesion of Candida albicans to the 3D-printed material was increased, while it was reduced for the heat-polymerized resin and the one used for milling, leading to the conclusion that using 3D-printed dentures increases the risk of denture stomatitis.
Schubert (22) also reported an increase in C. albicans colonization on 3D-printing and milling materials compared to heat-polymerized ones. Moreover, they compared three different 3D printing methods - poly jet modeling, digital light processing, and stereolithography - and concluded that the fabrication method does not matter for microbial colonization.
In his study, Koujan (18) also compared the adhesion of Candida albicans to the three types of polymers - heat-polymerized, for milling, and for 3D printing. The results showed a significant difference, with adhesion to the heat-polymerized resin and the one used for milling being smaller compared to adhesion to 3D-printing polymers.
Di Fiore (20) studied the adhesion of Lactobacillus salivarius, Streptococcus mutans and Candida albicans to heat-polymerized resin and 3D printing polymer. The results showed that adhesion to milling resins was the smallest, but if comparing conventional heat-polymerized and 3D-printing ones, adhesion to 3D-printing resins was smaller.
In a similar study Arutyunov (21) also compared the adhesion of C. albicans to different materials. The study included cold and heat-polymerized, milling, and 3D printed resins. The adhesion of microorganisms from the normal microbiota of the oral cavity was the greatest in cold-polymerized resin, followed by heat-polymerized, milling, and lastly the polymer for 3D printing. The adhesion of the Candida spp. was also the smallest to 3D-printed materials.
More and more studies worldwide are aimed at developing 3D printing materials with antibacterial effects. One way is by adding antibiotics or forming a film on the surface that prevents microbial adhesion, for example through a silicon coating (23) or a coating material of polydimethylsiloxane with added chlorhexidine (24). Another way is by including nanoparticles with antibacterial effects in the printing polymer (25).

Conclusion

Despite the increasingly widespread use of 3D technologies for the fabrication of removable dentures, some questions remain unresolved. The question of the biocompatibility of the materials used for 3D printed dentures is relevant, as confirmed by the active research of existing materials and the search for new materials with antibacterial properties.

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