Chapter

Alternative Denture Base Materials for Allergic Patients

Lavinia Cosmina Ardelean, Laura-Cristina Rusu and Codruta Victoria Tigmeanu

Abstract

Traditionally, a denture base is manufactured using a heat-cured acrylic resin. This type of resin was first used in dental labs in 1936, being a great step forward. Because of the many disadvantages as increased porosity, high water sorption, polymerization shrinkage, allergenic potential and citotoxicity due to the residual monomer, awkward flasking and packaging, and difficult processing, alternatives were continuously searched. Monomer-free and high-impact acrylics were developed, and gold plating of the denture base was experienced, in order to provide an alternative to allergic patients. Once polymers developed, new types of resins, such as polyamides (nylon), acetal, epoxy resins, styrene, polycarbonate, vinyl, urethane, polyether ether ketone (PEEK), became available on the dental market, accompanied by modern technologies, such as injection. CAD/CAM milled and 3D printed denture bases represent the present state of the art in this domain. Our chapter aims to present these alternative materials, which are safe to use in cases of allergic patients and guarantee a healthy oral environment and a high degree of comfort.

Keywords: denture base, acrylic resin, polymers, polyamides, acetal resin, PEEK, allergy, CAD/CAM milling, 3D printing

1. Introduction

Acrylic resins, which represented an important step forward in dentistry, have been used in manufacturing denture bases, artificial teeth, orthodontic appliances, maxillofacial prostheses, single-tooth or provisional restorations, as well as veneering materials, since the middle of the twentieth century [1].

Characterized by low density and thermal conductivity, good resistance to chemical solvents, acrylic resins became the most popular material for denture base fabrication because of the low fabrication cost, easy repair/reline, low weight, and aesthetical properties [2].

The most frequently used acrylic resins in dentistry are heat-cured. They seemed very promising at first, but, in time, it turned out that heat-cured acrylics had various shortcomings, such as poor resistance, dimensional stability issues, polymerization shrinkage, high degradation rate in wet environment, allergenic potential and citotoxicity due to the residual monomer, difficult processing, due to the awkward flasking and packing procedure (**Figure 1**) [3–6].

Figure 1.
Flasking and packing of heat-cured acrylic dentures.

Acrylic resin becomes porous and permeable after prolonged use in the mouth wet environment, also being prone to discoloration [7].

The consequence may be denture base fracture, allergic reactions, and improper seating [8].

The fracture of the acrylic denture base is a very common clinical problem, partly due to its complex geometry, which favors stress concentration in certain areas [9]. Most of upper denture base fractures are caused by fatigue and impact, whereas in case of the lower denture base, impact and low fracture toughness are the main causes [10]. One of the primary problems of acrylics is the impact failure when the denture is accidentally dropped on a hard surface and fatigue failure when the unfit denture base deforms repeatedly through occlusal forces [11].

According to literature data, 68% of the acrylic dentures break within a few years after fabrication [12].

Acrylics are also well known for their allergenic potential, their citotoxicity being mainly due to the residual monomer [13, 14].

The adverse reactions of the oral mucosa, in case of conventional acrylic resins, may also be induced by porosity (**Figure 2**), poor hygiene, degradation due to water sorption [15–17].

Inadequately cleaned dentures are subject to quick formation of a biofilm on their surface [18].

The anaerobic environment, characteristic under poorly cleaned denture bases, is associated with the proliferation of certain bacterial species, consequently leading to a pathogenic biofilm composition and inducing denture stomatitis by plaque accumulation (**Figure 3**) [19].

The often contaminated dentures of elderly patients may finally result in affecting the general health condition [20].

The high relative humidity of the oral environment, constant contact of the denture with saliva, cold and hot food and drinks, enzymes, bacteria, and the varying pH

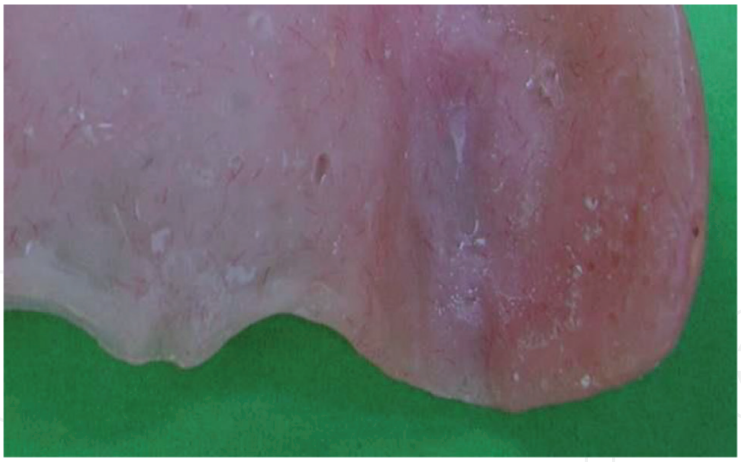

Figure 2.
Porous acrylic denture base.

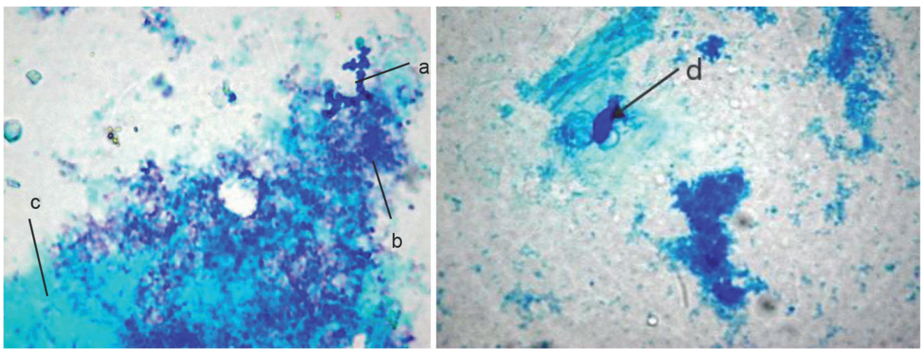

Figure 3.
Microbial flora found on the denture base surface: a. candida hyphae, b. cocci, c. mucinous conglomerate, d. trichomonas tenax (ATP Dragan coloration Ob. Im).

levels can severely affect the physical and mechanical properties of the denture [21]. Dental base materials, and especially acrylic resins, are prone to water sorption, as they tend to form hydrogen bonds with water molecules, which also leads to deteriorated physical and mechanical properties [22].

In order to overcome these disadvantages, various attempts have been made. One of the methods considered was gold plating, which has proved to increase the retention and overcome plaque accumulation. However, the method did not prevail, as the adhesion between the acrylic resin and the gold plated layer deteriorates and abrades.

Later on, reinforced acrylic resins, characterized by better resistance and low/none residual monomer, became available. Alternative polymer systems, such as polyamide, epoxy, styrene, acetal, polycarbonate, polyether ether ketone (PEEK), or vinyl resins, have been experimented, with promising results [23]. However, the desired denture base material has not been developed yet.

2. Alternative materials and techniques

There has been ongoing effort to enhance the strength and fatigue resistance of acrylic resins, by means of: reinforcement with the addition of filling materials, altering the chemistry of acrylic resins, and manufacturing alternative denture base materials [24, 25].

2.1 Reinforced acrylic resins

Previous studies have shown that favorable results in improving mechanical properties such as impact and transverse strength were overcome using various types of fillers such as glass, carbon, polylactic fiber, plyometric polyamide, ultra-high-molecular-weight polyethylene, aramid, rayon, ceramic particle (barium titanate, zirconium dioxide, silicon dioxide, hydroxyapatite, titanium dioxide, and calcium carbonate), and metal plates or wires [26–33].

There are numerous studies focusing on the effect of glass fibers on the mechanical qualities of acrylic resins, which reported improvement of tensile and flexural strength and esthetic results [34–39].

Different other materials have been used for reinforcement, such as viscose fibers, mica, juta, or vegetable fibers [40–42].

2.2 Alternative types of acrylic resins

Alternative manufacturing technologies for acrylic resins, which aimed at obtaining high-quality dentures, were constantly developed, using dedicated materials. These technologies including casting, injection, light curing, microwave polymerization, CAD/CAM milling, 3D printing have been more or less utilized [43].

Thermoplastic and CAD/CAM milled acrylates have a high impact rating resistance, long-term stability, being characterized by a dense and smooth surface. It's highly biocompatible, due to the absence of residual monomer, and has very good long-term stability because of limited water retention [44].

Acrylic resins have been one of the most common commercial materials used for the manufacture of 3D printed denture bases. However, there were some technical challenges that hinder the application of polymethyl methacrylate (PMMA), such as large shrinkage, low degree of one-time curing, poor mechanical strength, low bacterial resistance, etc., limiting their clinical applications [45].

Nevertheless, great progress has been made in manufacturing alternative resin materials with outstanding properties.

2.3 Light-cured urethane-based resins

Urethane-based resins have no allergic potential, due to the absence of methyl, ethyl, propyl, and butyl groups. Manufactured by light curing, full and partial urethane dentures do not need flasking, packing, and heat curing, which are time-consuming. The system is extremely efficient and consists of three wax-like types of resins: baseplate resin, setup resin, contour resin. A full denture base needs no more than 30 minutes to process, starting with complete setting of the master model. The "wax-up" is practically made on the denture's light-cured base, and after try-in, esthetic and phonetic approval, the final conditioning and light curing are carried out (**Figures 4**–7) [46].

2.4 Thermoplastic resins

Thermoplastic denture base materials include different types of hypoallergenic resins: polyamide (nylon), acetal, PEEK, epoxy, styrene, polycarbonate, vinyl, their most prominent advantages being higher elasticity, toxicological safety, and use of heat molding instead of chemical polymerization, which prevents polymerization shrinkage and related deformation [47, 48].

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Figure 4.
Baseplate resin before light curing.

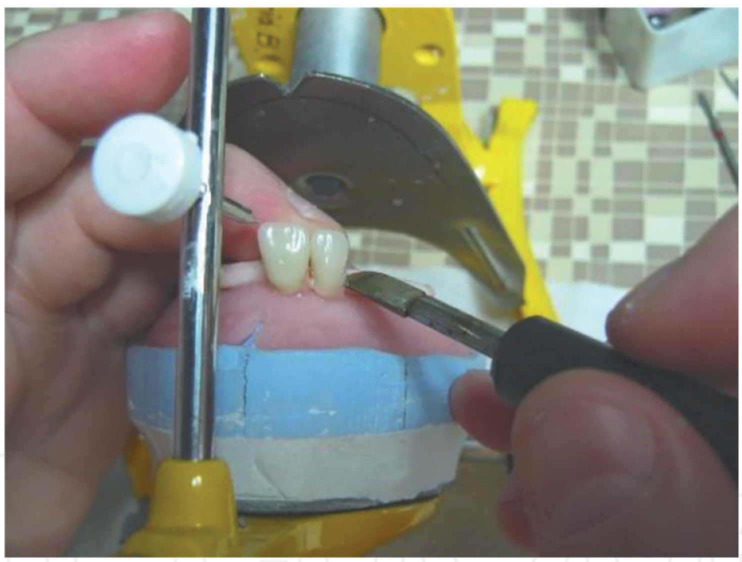

Figure 5.
Attaching the teeth to the cured baseplate, by using the setup resin.

Thermoplastic resins are monomer-free and consequently nontoxic and non-allergenic, with high biocompatibility. They provide better resistance, esthetic appearance, and lower weight, being much more comfortable for the patient [8, 49, 50].

Their manufacture implies injection by special devices (**Figure 8**), after preheating the material (at a temperature of 200–250°C), in granular form, wrapped in special cartridges (**Figure 9**), which prevents dosage errors. The technology excludes any chemical reaction [51].

Thermoplastic materials are suitable for the manufacturing of removable partial dentures, which totally or partially eliminate the metallic framework and clasps, resulting in the so-called “metal-free removable partial dentures.” If desired, any combination of the metallic framework or clasps with thermoplastic resin saddles and clasps is possible (**Figure 10**) [52, 53].

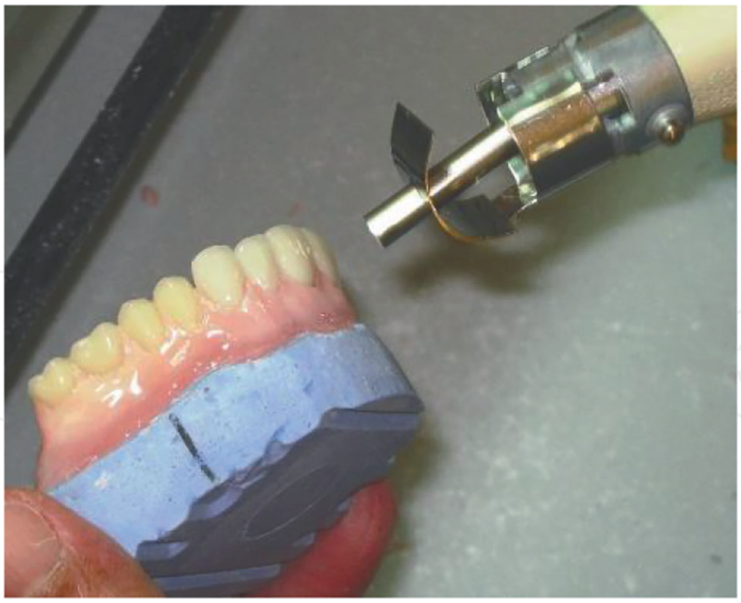

Figure 6.
Contour resin, overlaid on the baseplate, exposed setup resin and necks of the teeth, processed using the warm air gun to create a smooth surface.

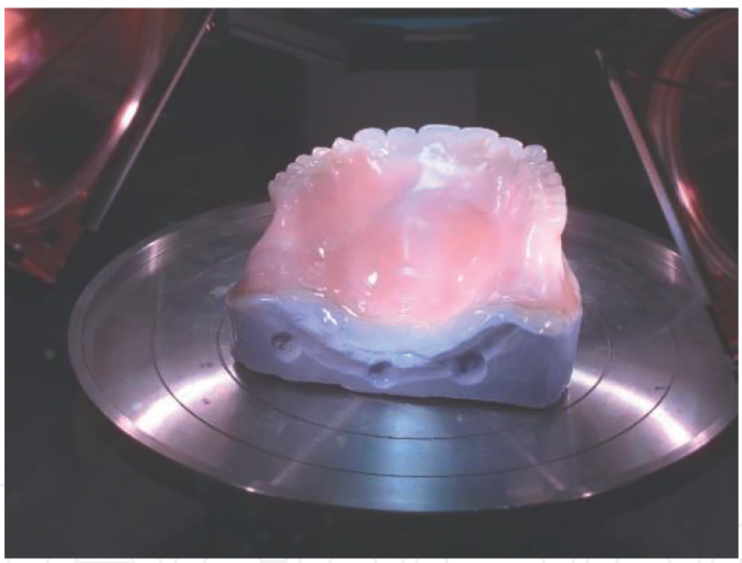

Figure 7.
Final light curing.

Figure 8.
Injection devices for thermoplatic resins.

Figure 9.
Thermoplastic grain-like resins, wrapped in cartridges.

Figure 10.
Combination between thermoplastic resin saddle, metallic and acetal clasps.

Their indications include: removable partial dentures, preformed clasps, removable partial denture frameworks, temporary or provisional crowns and bridges, full dentures, orthodontic appliances, anti-snoring devices, mouthguards and splints [54].

2.4.1 Polyamides

Polyamides (nylon) are the condensation result of a diamine and a dibasic acid [55].

In 1950, they were introduced in dentistry, as an alternative to denture acrylic base, and are being characterized by different degrees of flexibility, depending on the type of polyamide. Their main indications include patients with tissue allergies, cases of retentive dental fields (which are normally problematic for the insertion and disinsertion of the removable partial denture), and repeated denture fracture, as they are unbreakable [56, 57]. A polyamide denture may be bounced off the floor without cracking its base.

The types of polyamides include superflexible polyamide (**Figure 11**), extremely elastic, and medium-low flexibility polyamide, a half-soft comfortable material.

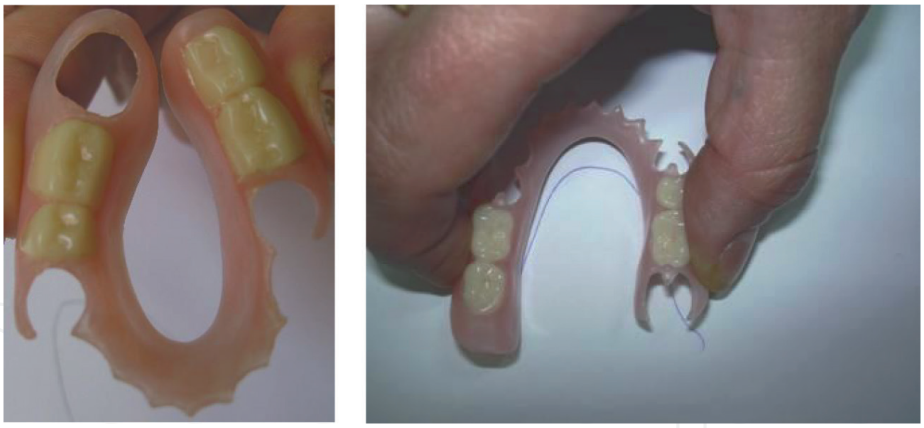

Figure 11.
Metal-free superflexible polyamide removable partial dentures.

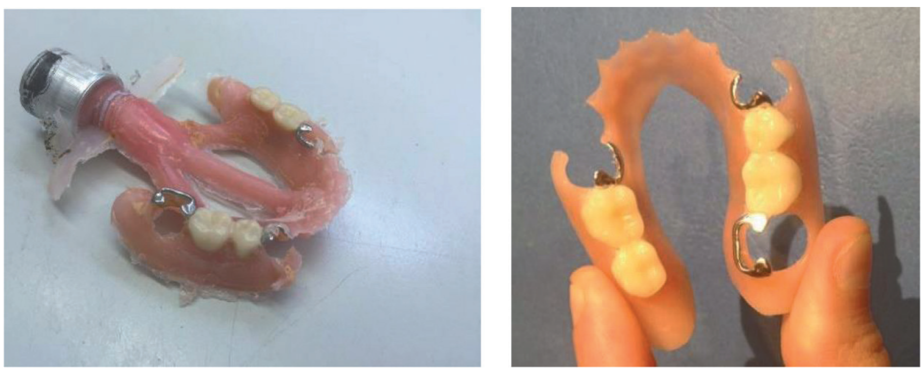

Figure 12.
Superflexible polyamide removable partial denture with metal clasps (right after injection and ready-to-go).

The clasps may be manufactured of the same material as the denture base. In the case of medium-low flexibility polyamide, ready-made clasps may be used. Metal clasps are also an option. (**Figure 12**).

2.4.2 Acetal resins

Acetal resins, also known as polyoxymethylene, are formed by the polymerization of formaldehyde. They have been used in dentistry since 1986, as alternative materials for denture base and clasps (**Figure 13**). Characterized by superior esthetics, acetal resins have been useful for low-weight removable partial dentures framework manufacturing in allergic patients [58]. They show high impact strength and elasticity [59]. Acetal resins are also indicated for Kemeny-type single unilateral partial dentures, provisional bridges, splints, and orthodontic appliances (**Figure 13**).

2.5 Polyether ether ketone

PEEK is a ketone-based semi-crystalline thermoplastic with excellent mechanical and chemical resistance properties, used in dentistry since 2002, for crowns, implant superstructures, fixed partial dentures, and removable partial denture frameworks and clasps (**Figure 14**) [60–63].

PEEK is highly biocompatible, insoluble, lightweight, with superior resistance to wear and fracture and elasticity comparable to bone. It may be optimized by adding

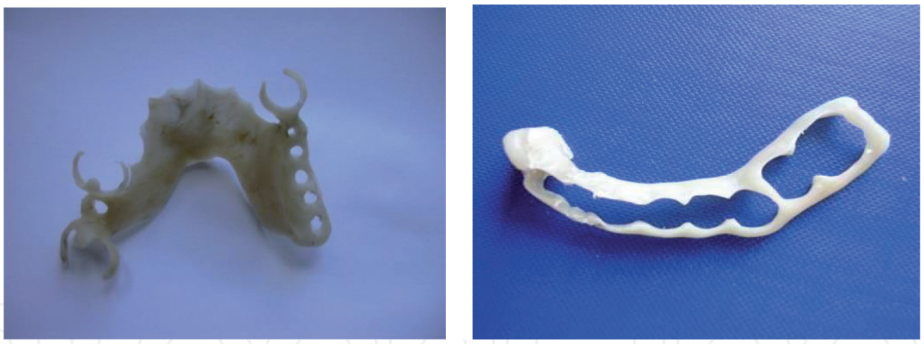

Figure 13.
Acetal framework and clasps; acetal splint.

Figure 14.
Removable partial denture with PEEK framework and clasps.

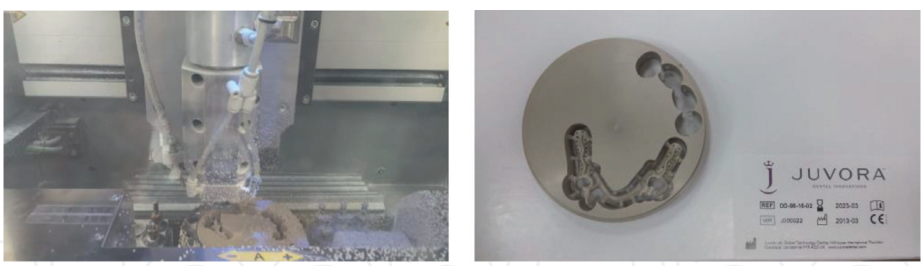

Figure 15.
CAD/CAM milled PEEK framework.

ceramic nanoparticles. The material may be injected (grains) at 400°C or milled (disks) using a CAD/CAM system (**Figure 15**) [44]. Recently, 3D printing using PEEK materials has been utilized. Direct-ink writing 3D printing uses soluble epoxy-functionalized PEEK (ePEEK) and fenchone, but the most widely used technique is fused deposition modeling (FDM), which requires increases in the nozzle and heating bed temperatures for PEEK materials [64–66].

2.6 CAD/CAM milled and 3D printed removable dentures

CAD/CAM systems, which enable manufacturing 3D objects, have been used in dentistry since 1980, at first for fixed prosthodontic restorations [67].

In the 1990s, the fabrication of removable prosthodontic restorations was attempted, using both 3D printing and milling technologies [68, 69].

They offer many advantages to both dentists and patients, such as reduced number of appointments and easily available spare dentures, as digital data are saved [70–72].

Compared with the traditional methods, the lab work can be completed more conveniently and cost-effectively. The high initial cost of the milling machine may be overcome by referring the data to a milling center, which will handle the actual manufacturing.

Currently, both CAD/CAM methods: substractive milling and additive printing, are being used for removable dentures manufacturing [73, 74]. By milling, the denture may be obtained as one item, teeth and denture base in a single body [75], or separate pieces, the artificial teeth requiring subsequent bonding to the denture base [76]. The latter is the most frequently used at present, as it allows using commercially available artificial teeth, with better esthetics and physical properties [77, 78].

In case of 3D printing, the light-curing resin used is quickly converted from a liquid to a solid under the action of ultraviolet or visible light. The emergence of nanomaterials provides a new way to improve the performance of 3D printed acrylics [79]. By incorporating TiO2, antibacterial effects have been obtained [80].

Cellulose nanocrystals were attempted to reinforce acrylic resins for 3D printing, with improved mechanical and antibacterial properties and no significant cytotoxic effect [81].

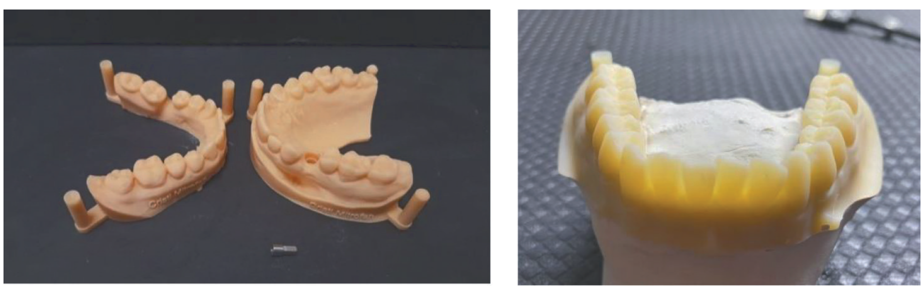

Figure 16.
3D printed high-precision models.

Figure 17.
3D printed working model for manufacturing a removable partial denture.

Light curing is a green technology and the main molding method involved in 3D printing of resin-based dental materials. When irradiated with light, the photosensitive resin undergoes stacking and curing [82].

It consists of three main technologies: stereolithogaphy, digital light processing (DLP), and fused deposition modeling (FDM). The distinctive feature of DLP technology is the diversity of materials, from thermoplastics to resins and ceramics, even zirconia paste. FDM, one of the cheapest and most popular 3D printing technologies in dentistry, enables using polylactic acid, polycarbonate, polyamide, acrylonitrile-butadiene-styrene copolymers [83].

Besides full dentures and frameworks for removable partial dentures, 3D printing dental resins are also indicated for crowns and bridges, high-precision working models (**Figures 16** and **17**), splints, custom trays.

3. Conclusion

Long-term deterioration of acrylic dentures in the oral environment is still an unsolved problem. Their allergic potential, mainly due to the residual monomer, is well known. New choices of resins, with better properties compared with acrylics, have been constantly developed for dental applications. Alternative processing technologies, such as casting, injection, light curing, CAD/CAM milling, and 3D printing, have been aiming to improving their qualities.

Choosing the right material for manufacturing full or removable partial dentures is very important because it has direct effect on their characteristics and lifetime, especially in case of allergic patients.

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Conflict of interest

The authors declare no conflict of interest.

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