Polymeric Alternatives in Manufacturing Removable Partial Dentures

LAVINIA COSMINA ARDELEAN[1], CRISTINA MARIA BORTUN[2]*, ANGELA CODRUTA PODARIU[3], LAURA CRISTINA RUSU[4]

[1] Victor Babes University of Medicine and Pharmacy Timisoara, Faculty of Dental Medicine, Department 1, Technology of Materials and Devices in Dental Medicine, 9 Revolutiei 1989 Blvd., 300070, Timisoara, Romania

[2] Victor Babes University of Medicine and Pharmacy Timisoara, Faculty of Dental Medicine, Department1, Dentures Technology, 9 Revolutiei 1989 Blvd., 300070, Timisoara, Romania

[3] Victor Babes University of Medicine and Pharmacy, Timisoara, Department1, Preventive Dentistry, Community Dentistry and Oral Health, 14 Splaiul Tudor Vladimirescu, 300173, Timisoara, Romania

[4] Victor Babes University of Medicine and Pharmacy Timisoara, Faculty of Dental Medicine, Department 1, Oral Pathology, 14 Splaiul Tudor Vladimirescu, 300173, Timisoara, Romania

Traditionally, removable partial dentures consist of a metallic framework, covered by acrylic saddles, which support acrylic or ceramic teeth. Because their shortcomings, new classes of resins/macromolecular compounds which promise better quality are nowadays available for manufacturing removable partial dentures: urethane-based resins, polyamides, acetal resins, high-performance polymers. Manufacturing these new materials implies alternative technologies like: injection, milling, light-curing. Using these alternative polymeric materials results in dentures with better resistance, elasticity, appearance and lower weight, which provide much more comfort to the patient.

Keywords: urethane-based resins, acrylic resins, high-performance polymers, acetal resins, polyamides

Traditionally, removable partial dentures consist of a metallic framework, covered by acrylic saddles, which support acrylic or ceramic teeth. Acrylic, in fact polymethyl methacrylate mixed with methyl methacrylate, is well known for its toxicity due to the residual monomer, the awkward wrapping system, difficult processing, and poor resistance [1]. In time, reinforced acrylic resins with better resistance or low/none residual monomer type came on the market [2]. To overcome the difficult processing, casted or injected acrylics were developed [3]. Many new classes of resins/macromolecular compounds which promise better quality and different properties such as elasticity are nowadays available for manufacturing removable partial dentures: polyurethane, polyamide. In the case of these alternative resins, injection or light-curing polymerization are frequently used [4,5].

CoCr alloys are traditionally used for the metallic framework, manufactured by casting. They are characterized by excellent corrosion resistance and superior mechanical properties and have diversified over time, aiming at creating both new products and new technologies to process them, including attempts to combine them with precious metals [6]. Nowadays CoCr alloys may also be manufactured by milling (bulk metal), sintering and 3D Printing Technologies (powder).

Despite their good resistance and corrosion, these type of alloys still has its shortcomings. That is the reason why alternatives, such as acetal resins or high performance polymers are now available for manufacturing the metallic framework.

Polyurethanes

Due to the absence of methyl, ethyl, propyl and butyl groups, urethane based resins do not generate contact allergies. Light-curing allows a rapid manufacturing of full and partial dentures, eliminating some time-consuming intermediate steps, like investing and heat-curing. The system consists of three types of resins, which can be handled like wax, being extremely efficient. A complete denture base may be ready in 30 min, after master model complete setting. The *wax-up i*s practically made on the denture's polymerized base and, after checking it, the rest of the pattern (saddles) is light-cured and the denture is finished [7,8] (fig. 1).

Fig. 1. Base plate resin before light-curing; Contour resin processed using the warm air gun.

Polyamides

Thermoplastic polyamides are materials characterized by different degrees of flexibility, depending on the type of polyamide. The superflexible polyamide is extremely elastic and virtually unbreakable, the medium-low flexibility polyamide is a half-soft material which offers superior comfort. Superflexible polyamide is especially useful for retentive dental fields, which would normally create problems with the insertion and disinsertion of the removable partial dentures. The clasps are made up of the same material as the denture base in the case of superflexible polyamide dentures. In the case of medium-low flexibility polyamide dentures ready-made clasps are an option [9]. Metal clasps may also be used [10] (fig. 2).

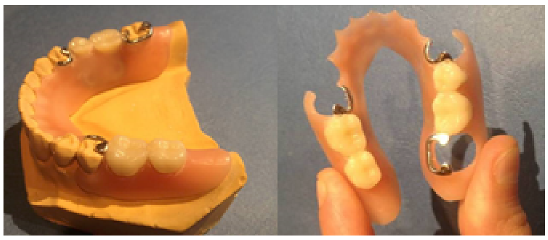

Fig. 2. Removable partial denture made up of superflexible polyamide with metal clasps.

* email: cristinabortun@gmail.com

Acetal resins

The removable partial dentures with acetal resin frameworks are more laborious to manufacture. The acetal framework has to be manufactured first, followed by the acrylic saddles and artificial teeth (fig. 3).

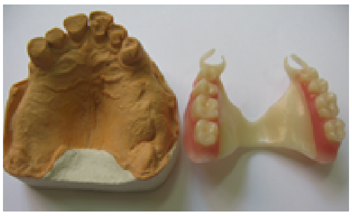

Fig. 3. Removable partial denture with acetal framework, clasps and acrylic saddles

These types of removable partial dentures have thin frameworks, with flexible and esthetic clasps, also being characterized by high mechanical resistance and low weight [11].

High Performance polymers

Poly(ether ether ketone) (PEEK), is a biocompatible thermoplastic material, with superior properties such as mechanical properties, resistance to wear and fracture and elasticity comparable to bone. PEEK for dental use may be optimized by adding ceramic 0.3-0.5μm particles. It is insolubile in water and ideal for allergic patients. The material may be injected (grains) at 400^{o}C or milled (disks) using a CAD/CAM system [12] (fig. 4).

A milled removable partial denture framework made up of PEEK (including clasps), weights only 1.36 grammes (fig. 5). The saddles are made of acrylate having the entire denture weights only 3.36 g [13] (fig. 5).

Fig. 4. PEEK milling disk; PEEK framework on a weighting scale

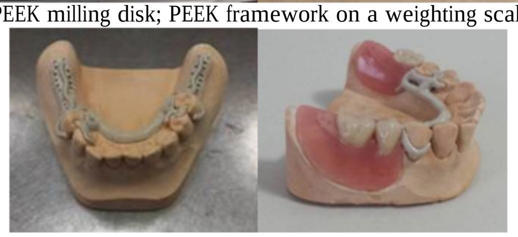

Fig. 5. PEEK framework; Finished denture

Experimental part

In order to compare some properties of classic acrylic resins to a urethane-based resin, samples (plates: 2 mm in thickness, 30 mm in length and 5 mm in width) were made accordingly: heat-cured for the acrylic resin and light-cured for the urethane-based one (fig. 6).

The acrylic resin took in consideration is a heat-cured, commonly used one, for manufacturing full and partial removable dentures.

The light-curing resins system used contains aliphatic urethane dimethacrylate-urethane oligomers (UDMA) as

Fig. 6. Heat-cured acrylic samples; Light-cured urethane-based samples

base monomers and acrylic copolymers, an inorganic submicronic silica filling, a light-curing initiating system and aditives.

Zwick Roell extensometer (Zwick GmbH & Co.) (fig. 7) was used to determine the moment of sample's breaking or fracture point and its elongation (fig. 8) and TestXpert software was used to standardize the applications.

The Young elasticity modulus (E) and ultimate tensile strength (Rm) were taken in consideration.

Fig.7. Determination of tensile mechanical resistance; The Zwick Roel extensometer in action

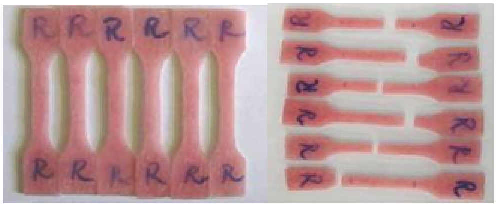

Fig. 8. Initial samples; Broken samples after stretching

The fracture toughness, which reflects the resistance to fracture and represents the energy required for a crack to propagate through a material until its complete fracture [14], of resins used in partial dentures technology, was also evaluated.

Fig. 9. Sample during compression experiment

The compression tests were performed with the static loading machine, model Zwick Roell of 5kN (Zwick GmbH & Co.), connected to a computer (TestXpert specic soft). The samples were compressed until breaking (fig. 9).

In order to get comparative results, measurements were undertaken with the same materials using different methods.

In case of single-edge-notched beam method (SENB) the bending tests were carried out on a Zwick-Roell 5 kN testing machine (Zwick GmbH & Co.) (fig. 7). The two halves of the broken samples were used for the measurement of the notch depth c.

Indentation strength method (IS) which uses a Vickers pyramid to determine the fracture toughness by analyzing the stress field at a crack tip was carried out by using a Vickers hardness tester, in the middle of the tensile surfaces of the beams at a load of 98 N, N for 15 s, magnitude which prevented radial cracks (fig. 10).

Results and discussions

The average values for the Young elasticity modulus (E) and ultimate tensile strength (Rm) after the sample's analysis are shown in table 1.

For fracture toughness evaluation, samples without initial cracks were considered, so that the value of the stress intensity factor- K_C depends only on sample's dimension and critical load value [14].

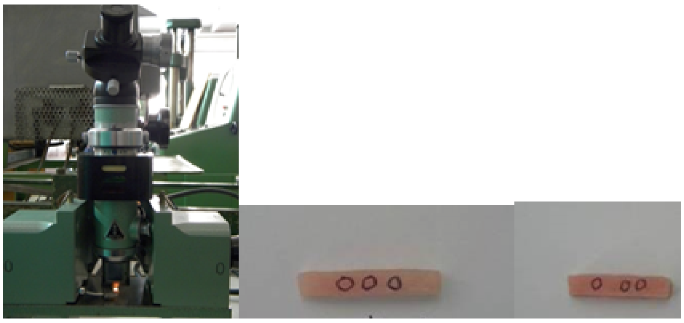

Fig. 10. The Vickers pyramid; The samples

Table 1
THE MECHANICAL PROPERTIES OF THE TWO TYPES OF RESINS

Materials	Determination of tensile mechanical resistance	
	E [MPa]	R_m [MPa]
Heat-cured acrylic resin	1625.8	53.78
Urethane-based resin	2628.9	95.26

Table 2
MEASUREMENT RESULTS

Material	Hardness H [MPa]	Fracture toughness K_{IC} [Mpa√m] SENB	Fracture toughness K_{IC} [Mpa√m] IS
Heat-cured acrylic resin	29.58	2.52	2.33 (v=0.05 mm/min)
Urethane-based resin	25.45	3.35	3.29 (v=0.05 mm/min)

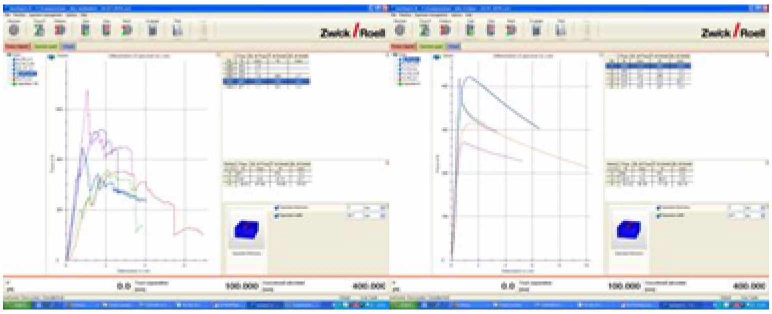

Fig. 11. Force-displacement diagrams resulted after caring out compression test: acrylic resin; urethane-based resin

Results obtained by strength indentation method (IS) are comparable to those obtained by SENB method at low loading rates (~0.05 mm/min) as shown in table 2. Force-displacement diagrams resulted after caring out compression test are shown in figure 11.

The results obtained for the two tested resins show noticeable differences, the urethane-based resin showing the higher value for fracture toughness.

When inserted in the mouth, because of the humid environment, the mechanical properties values decrease distinctly. The differences noticed between humid and dry environment indicate the evident role of the saliva in the biodegradation of the denture base polymers [15].

Conclusions

There is an evident difference among the tested materials. The heat-curing resin has a lower value of the elasticity modulus, ultimate tensile strength and fracture toughness than the urethane-based resins. In the case of resins used in dental prosthetics, in addition to aesthetic aspect and strength, elasticity and elongation are also important features [16].

The fracture toughness depends on the type and the nature of the polymer and the reinforcement added components. An increase in the fracture toughness can be achieved by adding reinforcement fibres which prevent or slow down the crack growth or by adding rubber-like substances, which increase elasticity [14].

New choices of resins, with better properties compared to acrylics are now suitable for dental applications. Alternative technologies for processing dental resins, like casting, injection, light-curing and milling are meant to improve their clinical performances [17].

Acknowledgements: The research leading to these results has received funding from BIOMAT-INOVA research program 2016-2017, Scientific Association ROMANIAN SOCIETY FOR BIOMATERIALS under the project contract no 34/12.12.2016

References

ARDELEAN, L., BORTUN, C., MOTOC, M., RUSU, L., Mat.Plast., **47**, no. 4, 2010, p.433

1.RUSU, L.C, URECHESCU, H., ARDELEAN, L., LEVAI, M.C., PRICOP, M., Mat. Plast., **52**, no. 3, 2015, p.413.
2.ARDELEAN, L., RUSU, L.C., BRATU, D.C., BORTUN, C.M., Mat.Plast., **50**, no. 2, 2013, p. 93.
3.ARDELEAN, L., BORTUN, C., MOTOC, M., RUSU, L., MOTOC, A.., Mat.Plast., **45**, no. 2, 2008, p. 214.
4.ARDELEAN, L., BORTUN, C., MOTOC, M., RUSU, L.C., Mat.Plast., **47**, no. 4, 2010, p. 433.
5.ARDELEAN, L., BORTUN, C., PODARIU, A.C., RUSU, L.C., Mat.Plast., **49**, no. 1, 2012, p. 30.
6.ARDELEAN, L., RECLARU, L., BORTUN, C.M., RUSU, L.C., Assessment of Dental Alloys by Different Methods, In: Superalloys. Ed. InTech, Rjeka, Croatia, 2015, p. 141-170.
7.BORTUN, C., CERNESCU, A., GHIBAN, N., FAUR, N., GHIBAN, B, GOMBOS, O., PODARIU, A.C., Mat.Plast., **47**, no. 4, 2010, p. 457.
8.BORTUN, C.M, ARDELEAN, L., RUSU, L.C, MARCAUTEANU, C., Rev.Chim.(Bucharest), **63**, no. 4, 2012, p. 428.
9.ARDELEAN L, BORTUN CM, PODARIU AC, RUSU LC., Thermoplastic Resins Used in Dentistry. In: Thermoplastic Elastomers. Synthesis and Applications, ed. InTech, Rjeka, Croatia, 2015, p. 145-167.
10.MERMEZE AI., Rehabilitation of partial edentation with a flexible denture with metallic clasps. [thesis]. Timisoara: Victor Babes University of Medicine and Pharmacy Timisoara, 2016.
11.ARDELEAN, L, BORTUN, C, MOTOC, M., Mat.Plast., **44**, no. 4, 2007, p. 345.
12.PEEK-A New Material for CADCAM Dentistry [Internet]. 2014. Available from: https://juvoradental.com/en/2014/0613/peek-a-new-material-for-cadcam-dentistry.
13.CICEOI AI., Removable partial denture with non-metallic framework [thesis]. Timisoara: Victor Babes University of Medicine and Pharmacy Timisoara, 2016.
14.BOLOS, O.C, BORTUN, C.M, CERNESCU, A., ARDELEAN, L., BOLOS, A., RUSU, L.C., Mat.Plast., **50**, no. 1, 2013, p. 28.
15.BORTUN, CM., CERNESCU, A., ARDELEAN, L., Mat.Plast., **49**, no. 1, 2012, p. 5.
16.BORTUN, C, GHIBAN, B., SANDU, L, FAUR N, GHIBAN, N., CERNESCU, A.,. Mat.Plast., **45**, no. 4, 2008, p. 362.
17.ARDELEAN L, BORTUN C, PODARIU A, RUSU L., Manufacture of Different Types of Thermoplastic. In: Thermoplastic - Composite Materials, Ed. InTech, Rjeka, Croatia, 2012, p. 25-48.

Manuscript received: 26.05.2017