Aesthetic Importance of Resin based Dental Materials used for Orthodontic Appliances

ANAMARIA BECHIR[1], MARIANA PACURAR[2], EDWIN SEVER BECHIR[2], MONICA RALUCA COMANEANU[1]*, MANUELA CHIBELEAN CIRES[2], MARIUS MARIS[1], HORIA BARBU[1]

[1] Titu Maiorescu University of Bucharest, Faculty of Dentistry, Department of Dental Specialties, 67A Gheorghe Petrascu Str., Bucharest, Romania

[2] Medicine and Pharmacy University of Tirgu Mures, Faculty of Dentistry, 38 Gheorghe Marinescu Str., Tirgu Mures, Romania

Orthodontic appliances are intraoral devices used to induce changes in relations between the teeth and the underlying bone structures. Removable orthodontic appliances, which contribute to the alignment of misaligned teeth and to the development of maxillaries, are not fixed to teeth and can be inserted/removed easily on/off the teeth of the dental arches. The aim of this study was to evaluate some characteristics of removable orthodontic appliances achieved by two different technologies (heat-curing and vacuum-forming), realised by using two dental materials (Superacryl Plus-SpofaDental thermo-cured acrylic resin and Biocryl® C and Biocryl® M -Scheu thermoplastic materials). The study included 123 adolescent patients, to which were manufactured one or two removable orthodontic appliances, on one or both of the dental arches. A total of 141 removable orthodontic appliances were manufactured for the selected adolescent patients. The manufacturing of all types of removable orthodontic appliances followed the same technological procedures, specific to each type of used material. The results of the study demonstrate that the aesthetic effect of the two dental materials presented different results, and the best results were observed at the orthodontic appliances achieved by the vacuum-forming technology, using Biocryl® C and Biocryl® M–Scheu thermoplastic materials.

Keywords: removable orthodontic appliances, materials, technologies, aesthetics

In dentistry, non metallic materials for appliances manufacturing have a long tradition [1]. Resins represented a major step forward in dentistry, the first acrylic thermo-cured resins coming up in 1936 [2]. Continuous development and progress of the polymer's industry with application in general and dental medicine have their ground in the importance of these biomaterials in the health domain. Acrylic resins dominated dentures technology for several decades, being used for denture and removable orthodontic bases, artificial teeth, veneering materials, dental restorations. The use of these resins in different technological variants for the orthodontic and prosthetic restoration is benefic from childhood till geriatric period [3-6].

Polymethyl methacrylate (PMMA) is a transparent thermoplastic, often used as a lightweight or shatter-resistant alternative to glass. Chemically, it is the synthetic polymer of methyl methacrylate. Generally, radical initiation is used (including living polymerization methods), but anionic polymerization of PMMA can also be performed [7].

Acrylic resins are known as polymethyl methacrylate or PMMA, which are synthetically obtained and can be modeled, packed or injected into molds during an initial plastic phase which solidify through a chemical reaction of polymerization [8- 11].

Polymerization can be initiated chemically by mixing the two components, of which one contains the initiator and one the activator, usually peroxide 1% as initiator and tertiary amine 0.5% as activator. The polymerization of methyl-methacrylate in polymethyl-methacrylate is presented in figure 1.

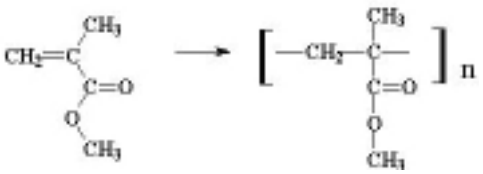

Fig. 1. The polymerization of methyl-metacrylate in polymethylmetacrylate (PMMA)

Among the achieving technologies of the dentures, can be distinguished heat-curing, self-curing, injection, light-curing, casting and microwave use [12].

An orthodontic appliance is a device that applies force to the teeth and their supporting structures, to produce changes in the relationship of the teeth and the skeletal structures, and to control their growth and development, by using gentle force. The orthodontic appliances are used in orthodontic therapy to move the teeth into esthetical/physiological positions, such as better alignment within the dental arch or with the opposing dentition [13].

Removable orthodontic appliances are not fixed to teeth and can be easily removed and reinserted into mouth, by the patient, and contribute to improved tooth position and jaw relationship. Their component parts consist of wires and screws, held together by a plastic base [14].

Experimental part

Materials and Methods

The adolescent patients included in the survey were selected after a detailed medical history, taking part only those who have expressed the desire to participate in the trial. Age distribution was close (between 12-21 years).

* *email: monica_tarcolea@yahoo.co.uk; Tel.: 0723860069*

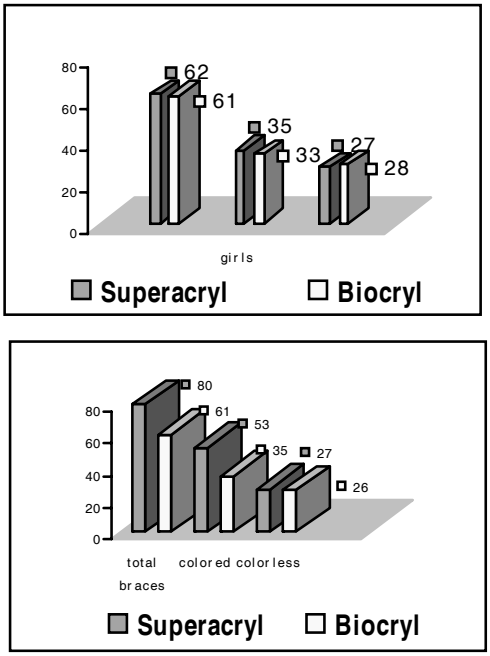

Fig. 2. The distribution of adolescent patients into batches, after gender and the colour of used resin for appliances

We selected 123 adolescent patients who presented different types of dento-alveolar incongruence, which necessitates a minimum of 24 months of orthodontic treatment with removable orthodontic devices.

The comparative clinical and technological trials have been conducted on two groups of patients. For the first group, represented by 62 teenagers (35 girls and 27 boys), 80 removable orthodontic appliances (27 colorless and 53 colored) were manufactured from *Superacryl Prima* - SpofaDental acrylic resin, using the heat-curing technology. For the second group of 61 teenagers (33 girls and 28 boys), 61 removable orthodontic appliances were performed, 26 from colorless *Biocryl® C* and 35 from colored *Biocryl® M* - Scheu polymer, using the vacuum-forming technology. The distribution of adolescent patients into the batches, after gender, used resin and the color of resin are presented in figure 2.

The presentation manner of the *Superacryl Plus* – SpofaDental resin for thermo-cured braces is a two component system, powder and transparent liquid.

The removable braces were manufactured following the same clinical and technical steps, in accordance to the technology and the chosen material. We pursued the technical and clinical phases of the manufacturing the removable braces, manufactured from the two types of polymers, in order to ascertain the differences in their manufacturing.

Superacryl Plus - SpofaDental acrylic resin powder is solid at room temperature, and is comprised of polymethyl methacrylate, initiator, pigments, opacificators, plasticizers, and particles of organic and inorganic fibers. The particles are spherical and their coalescence was avoided by adding inert substances. Benzoylperoxide (0.5-2% percent by weight) incorporated into the structure of polymethyl methacrylate, is a donor of free radicals during the heat curing process of the acrylate paste (paste which results by mixing the powder with the liquid). Also, to facilitate the formation of acrylic powder pearls, a plasticizer is incorporated, plasticizer represented by a monomer with larger groups than methyl-methacrylate. Their softening temperature is around 125°C and above this temperature, the depolymerization of powder occurs. The liquid of heat cured acrylic resins contains monomer (methyl methacrylate), inhibitors, plasticizers and hardening agents. The monomer is not chemically stable and tends to spontaneous polymerization under the action of light and heat, reason for which an antioxidant is added (hydroquinone, 0.006% by mass), having also an inhibitor of polymerization role, which allows fluid preservation. Polymerization reaction is initiated at a temperature of 65°C in the entire mass of material. The polymerization of methyl methacrylate occurs with a strong contraction (21%), and therefore it is mixed with polymethyl methacrylate powder [15]. The preparation of acrylic paste consists by mixing the liquid with the powder into a bowl of glass or plastic. Initially, the mixture looks like a sandy mass, which later turns into a homogeneous mass [16].

Superacryl Prima resin polymerize through heat. The removable braces were manufactured by the indirect method, after the impression of dental arches and the bite registration where it was necessarily. The 80 removable braces of the first batch of 61 adolescent patients were manufactured by fast polymerization (1 1/2 h at 74°C and boiling for 30 minutes at 100°C), followed by the unpacking, processing, finishing and polishing of removable orthodontic appliances.

Fig. 3. The presentation of packed Biocryl® C and Biocryl® M -Scheu plates, used in our researches

According to the manufacturer, the polymeric material *Biocryl® C* and *Biocryl®M* – Scheu (fig. 3) is a break-resistant acrylic blanks, made of pure PMMA material, monomer free, without irritant agent, without allergic reaction, which bonds to acrylic resins and which can be used for a large variety of removable appliances designed for retention or minor tooth movement, orthodontic plates and retainers.

Vacuum thermoforming is a process that transforms the plastic sheets into three dimensional shapes, through their application of heat and pressure. Basically during vacuum forming processes, plastic material is heated until it becomes pliable, and then it is placed over a mould and drawn in by a vacuum until it takes on the desired shape. Vacuum thermoforming is a huge method for producing plastic parts that has sharp details and fits nicely to specific products. The vacuum forming process, in its simplest form, consists essentially of inserting a thermoplastic sheet in a cold state into the forming clamp area, heating it to the desired temperature either with just a surface heater or with twin heaters and then raising a mould from below. The trapped air is evacuated with the assistance of a vacuum system and once cooled a reverse air supply is activated to release the plastic part from the mould. The typical process steps can be identified as follows: clamping, heating with sheet level activated, pre-stretch, forming with plug assist, cooling with air and spray mist, release and trimming.

Appliances made from *Biocryl®* discs were manufactured on the Scheu Biostar® V Machine Type 05, positive pressure thermal-forming machine. The Biostar® V Machine provides flawless adaptation by using a combination of positive pressure and forming the heated

Fig. 4. The aspect of Biostar® V type 05 machine - Scheu Dental

side of the material over the model. It is a versatile pressure molding machine for all applications in dental pressure molding and orthodontics with scan technology and increased working pressure of 6 bars. The thermally controlled infrared heater reaches working temperature in one second and all important data are printed on each single sheet and are read by the scanner and shown on the large display. Their large model cup facilitates embedding mounted models and the pellet container ensures optimum dispensing and storing of pellets. Present acoustic and optical control of heating and cooling times as well as of all working steps. The characteristics of Biostar® V Machine Type05 used in our researches are: power: 230 V, 850 W; working pressure: 0.5 – 6.0 bar; measurements (W x H x L): 450 x 230 x 260 mm; weight: 14 kg (fig. 4).

The models should be poured with regular dental plaster, but, in the case of hard elastic foils use, deformations of the foil and breakage of model teeth are possible. Therefore it is generally recommended to use a duplicate model. In case of hard elastic foils and if only parts of the model are moulded (e.g. splints), the model should be embedded in pellets in order to avoid overstretching the foil. If soft elastic foils are used, the trimmed and insulated models should be placed on the working platform. The vacuum thermoforming equipment consists of infrared heater, forming table, clamping frame and reservoir for air pressure supply. During the forming stage the model was positioned on the forming table, the thermoplastic sheet was positioned in the clamping ring above the metal model and below the heating element. The power and the heating circuit are switched on, after setting the code, the infrared heater reaches the working temperature and the thermoformed sheet can be plasticized (fig. 5).

The removable braces were laid on the teeth of the dental arch/arches, and were used for at least 8-10 h of 24 h.

Before the impression of dental arches, the adolescent patients were asked to choose the desired shade of colour for the future brace.

After the period of adjustment with the orthodontic devices, we conducted every six months, for 2 years, the patients monitoring. The objective and subjective ascertainments of adolescents were recorded after verification of the existence/inexistence of decubitus

Fig. 5. Technical steps in the manufacturing vaccum-thermoformed braces

lesions; changes in color of the polymeric base of the movable orthodontic appliances; of allergic reactions in oral mucosa; fissure/fracture in the orthodontic appliance; physical/mental discomfort in the use of the orthodontic device.

Results and discussions

The objective and subjective ascertainments of adolescents recorded at every six months are presented in table 1.

We note that, in the all determinations, the majority of adolescent patients presented one or more of listed above criteria.

According to the survey results, we found that the orthodontic appliances manufactured from Biocryl polymer showed generally superior qualities to those carried out from Superacryl Prima.

Also, we need to mention the fact that orthodontic braces realized from Biocryl® polymer require a much shorter manufacturing time than those achieved by the resin Superacryl Prima.

We must note that colored braces are preferred by the teenager boys and girls aged between 12-14 years in 98% of cases, and the colorless braces are preferred by adolescent girls, after 15 years old in 92% of cases.

The greatest advantages of vacuum thermoforming are the ease of handling, constant heating temperature regardless the external influence and power supply, short working time, less technical phases [17- 19]. The thermoforming process has been used to produce a variety of dental restorations that include braces, splints, mould duplication, mouth guards, implant positioners, occlusal splints, record bases, etc [20].

The impact of the so-called "cosmetic" dentistry has increased substantially in recent years. This is likely to have

Table 1

OBJECTIVE AND SUBJECTIVE ASCERTAINMENTS OF ADOLESCENTS

	80 Superacryl Plus-SpofaDental braces								Biocryl® - Scheu braces							
	27 colorless				53 colored				26 colorless				35 colored			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Decubitus lesions	6	4	3	2	9	8	4	2	2	1	-	-	3	1	-	-
Changes in color	2	3	4	4	3	5	5	6	-	-	1	1	-	-	1	1
Allergic reactions	2	1	-	-	2	1	1	-	-	-	-	-	-	-	-	-
Fracture	-	1	2	3	1	2	2	4	-	-	-	1	-	-	-	1
Discomfort	2	1	-	-	3	3	1	-	1	1	-	-	2	-	-	-
Without symptomatology	18	20	21	22	37	39	44	47	24	24	25	25	32	34	34	34

increased the public's awareness of their dental appearance [21].

Special cases are represented by the inverted occlusions, which can be corrected by using the orthodontic splint with inclined plane. In the case of poor aesthetics of the orthodontic appliance, because of their emotional ages, behavioral disturbances can appear in the adolescent patients [22]. A particular situation is represented by the inverted frontal occlusion, which uses for correction the orthodontic splint with inclined plane cemented on the lower anterior teeth. Being visible and because the treatment should only take of 7-8 weeks, it is necessary to manufacture the splint with inclined plane, out of an aesthetic material like *Biocryl® C*, fixed on the lower anterior teeth with aesthetic dental cement (fig. 6).

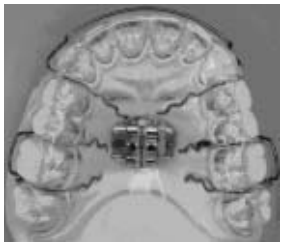

Fig.6. Variants of colorless, aesthetic orthodontic plates obtained through the vaccum-thermoforming technique: removable orthodontic appliance with inclined plane in lateral area

The advantages of thermo-cured orthodontic appliances consist of their lower cost, they can be achieved in diverse models, and the technician is able to introduce multiple active elements in the acrylic base. The disadvantages are represented by their porosity, the presence of residual monomer which is a potential allergen, the finishing time is increased, they are more brittle and present uneven thickness.

The advantages of vacuum-thermoformed orthodontic appliances are represented by the absence of residual monomer, their uniform thickness, clearly superior finishing.

The disadvantages consist of their slightly higher cost, fewer active elements may be introduced in their polymeric base, their limited range of colours.

Due to their heterogeneous structure and complex nature it is difficult to classify the dental resins. Based on the thermal behaviour, they are classified as *thermoplastic* (refers to resins that are softened and moulded under heat and pressure without any chemical changes occurring; they are cooled after moulding; are fusible and are usually soluble in organic solvents. E.g., polymethyl methacrylate, polyvinyl acrylics and polystyrene) and *thermo set* (refers to resins in which a chemical reaction takes place during moulding; the final product is chemically different from the original substance; these cannot be softened by reheating like the thermoplastic resins; they are generally infusible and insoluble (E.g., Cross-linked polymethyl methacrylate, silicones etc.) [23]. If the heat curing temperature is raised suddenly, a variety of polymerization centers will appears, with the formation of many short-chain polymers that will determine a structure with a high degree of hardening, which leads to low hardness of the final polymer. Slower polymerizations produce the formation of a smaller number of chains, which have a much higher molecular weight. Thus, progressively increasing the paste viscosity, easier access of the monomer and hardening agent is provided, which will lead to the formation of chains and reticular structures. The presence of large amounts of residual monomer and uncured hardening agent, through their plasticizing action, will cause unfavorable mechanical properties and optical qualities of the resin of restoration [15].

Monomer boils at 100.3°C, and if the material is allowed to reach this temperature before polymerization has occurred, then the monomer will vaporize and cause porosity in the base [24].

PMMA porosity has been reported to be associated with poor aesthetics, due to the update of stains and oral fluids. This may in turn lead to the harbouring of oral micro-organisms, and subsequent oral Candida infection [25]. Porosity levels of above 11% are observed to adversely affect the mechanical properties, including strength of PMMA denture base materials [26]. Porosity has been attributed to a variety of factors that include the followings: air entrapped during mixing, monomer contraction during polymerization, monomer vaporization associated with the exothermic reaction and the presence of residual monomer, insufficient mixing of monomer and polymer, processing temperature higher than 74 °C, packing the mold and inadequate compression on the flask may cause porosity in denture base resin [27]. The porosity is caused too by the incorporation of air bubbles when the acrylic resin is poured in the mould or by using an overheat cycling of thermo-polymerization (boiling the monomer) (fig. 7) [28].

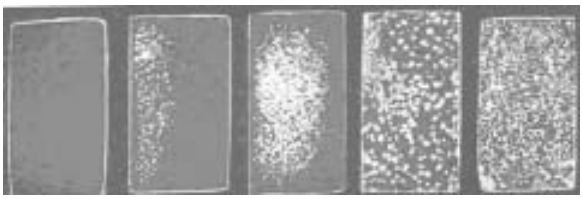

Fig.7. Typical porosity of heat activated denture base resin (left: properly polymerized; other: too fast heating) [24]

It is important that the acrylic is fully cured, in order to avoid a high level of excess irritant monomer [29].

According to Negrutiu M. and al [30], the disadvantages of thermo-cured acrylic resins are connected to increased porosity, high water retention, volume variations and irritating effect of the residual monomer (organic solvent, hepatotoxic), awkward wrapping system, difficult processing, together with the polymer development, have led to alternative materials such as polyamides (nylon), acetal resins, epoxy resins, polystyrene, polycarbonate resins etc.

In orthodontics, the polymeric part of orthodontic appliances could be a hazard for patients because high residual monomer contents can lead to allergic reactions. In addition, water uptake, color stability, and mechanical properties are influenced by the degree of conversion [31].

The results of Kopperud&al suggest that prefabricated thermoplastic plates should be preferred for patients with an allergy to methacrylate [32].

Nowadays, thermoplastic appliances are in high demand both from patients and clinicians', dictating that search for scientific proof is essential since it may reinforce or discourage the clinicians decision for their use as an approach to orthodontic retention [33].

Removable appliances are best suited to those situations where gross manipulation of a tooth (or a small group of teeth) is warranted, not those in which detailed or precise movements are a functional or cosmetic goal. The advantages in use removable braces consist of the facilitation of oral hygiene, the relatively simple chairside adjustments and potentially of less expense. The disadvantages are: easily lost or broken, rather imprecise tooth movement, entirely dependent upon patient cooperation [34].

Singh G. [35] consider that, among the advantages of removable braces obtained by vacuum-forming technology are included the enhanced patient comfort (which increases patient compliance providing better chances of retention), the aesthetic, ease of oral hygiene maintenance, easily removed and replaced by patients at will, easy to fabricate, good retention and stability.

Jagger et al. 2003 demonstrated that there was no significant difference in the accuracy of adaptation of the thermoformed materials over time [36].

Interactions between oral microbes and the polymer dental materials may also occur, although little information is available regarding this possibility. An *in vitro* study conducted by Willershausen et al. has shown that bacteria can colonize the surfaces of resin-based dental materials. They have also found an increase in the roughness, suggesting some surface degradation effect caused by bacteria colonization [37].

Conclusions

It is essential to follow accurate technological phases for manufacturing the appliances, in order to obtain devices with optical and mechanical properties in accordance to the current requirements.

The achievements of orthodontic appliances by vacuum thermoforming technology represent an alternative to the classical heat cured technique, being part of the new methods offered by the producers, for improving the clinical performances of these dental appliances.

Within the limitations of this study, we conclude that vacuum thermoformed braces presented better performances in time and a better aesthetic in comparison with the conventional heat cured orthodontic appliances, which presented interferences even in their coloristic appearance.

References

1.ARDELEAN L., RUSU L.C., BRATU D.C., BORTUN C.M., Mat. Plast.., **50**, no. 2, 2013, 93-96

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

3.BORTUN C, GHIBAN B, SANDU L, FAUR N, GHIBAN N, CERNESCU A.., Mat. Plast., **45**. no. 4, 2008, p.:362

4.PODARIU A., JUMANCA, D., GALUSCAN A., VACARU R., MUNTEANU, R.: Tratat de Prevenţie Oro-Dentară, Editura Marineasa, 2006

5.FAUR N, BORTUN C, MARAVINA L, CERNESCU A, GOMBOS O. Durability studies for complete dentures, Key Engineering Materials 2010; 417-418:725-728

6.GHIBAN N., BORTUN C.M., BORDEASU I., GHIBAN B., FAUR N., CERNESCU A., HANGANU S.C.., Mat. Plast., **47**, no.2, 2010, p.240

7.*** http://en.wikipedia.org/wiki/Poly%28methyl_methacrylate%29

8.PHOENIX R.D., MANSUETO M.A., ACKERMAN N.A., JONES R.E.: Evaluation of mechanical and thermal properties of commonly used denture base resins, J. of Prosth., 13, 1, 2004, p. 17-24

9.BORTUN C.M., ARDELEAN L., RUSU L.C., MARCAUTEANU C., Rev. Chim., (Bucharest), **63**, no. 4, 2012, p. 428

10.CAZACU M., RACLES C., VLAD A., ANTOHE M., FORNA N.: Silicone-based Composite for Relining of Removable Dental Prosthesis. Journal of Composite Materials, 43 (19), pp. 2045-2055, 2009

11.CHECHERITA L., BELDIMAN M.A., STAMATIN O., FOIA L., FORNA N.C., Rev. Chim. (Bucharest), **64**, no.8, 2013, p. 864

12.BORTUN C.M., CERNESCU A., ARDELEAN L., Mat. Plast., **49**, no. 1, 2012, p. 5

13.MILLER-KEANE, O'TOOLE: Miller-Keane Encyclopedia & Dictionary of Medicine, Nursing & Allied Health - Revised Reprint, 7th Edition, Saunders Ed., 2005

14.***http://medical-dictionary.thefreedictionary.com/removable+orthodontic+appliance

15.BECHIR A., GHERGIC D.L., BECHIR E.S., SMATREA O., POPESCU A.I., GIOGA C.: Application of Polymeric Impak Material to Mitigate the Cranio-Mandibular Effects of Stress, Annals of DAAAM for 2011 &Proceedings of the 22nd International DAAAM Symposium, Editor Katalinic B., Published by DAAAM International, Vienna, Austria 2011 ISBN 978-3-901509-83-4, ISSN 1726-9679, pp 0659-0660

16.SHALABY S.W.: Polymers for Dental and Orthopedic Applications (Advances in Polymeric Biomaterials), CRC Press Publisher, Boca Raton, Fl. United States, 1st edition, 2006, ISBN: 0849315301

17.AHMAD Z.M., AL-ALI A.A., SHEET O.A.: Linear Dimensional Change and Accuracy of Fit of Positive Pressure; Thermo–Formed Prosthodontic Materials, Al–Rafidain Dent J, 2012, 12(2): 206-217

18.SCHMIDT M., MAOULT Y., MONTEIX L.: Modelling of infrared heating of thermoplastic sheet used in thermoforming process, Journal of Materials Processing Technology, 2003; 225-231

19.*** www.Scheu-dental.com

20.JAGGER R., OKDEH A.: Thermoforming polymethyl methacrylate, J. Prosthet. Dent., 1995; 74:542-545

21.BURKE F.J.T., KELLEHER M.G.D., WILSON N., BISHOP K.: Introducing the Concept of Pragmatic Esthetics, with Special Reference to the Treatment of Tooth Wear, Journal of Esthetic and Restorative Dentistry, 2011, 23: 277–293

22.SAGAR M.: Role of removable appliances in contemporary Orthodontics, The Orthodontic CYBER Journal, May 2012

23.GANIGA R.: Denture Base Materials 12, Dec 16, 2011, http://www.scribd.com/doc/75871387/Denture-Base-Materials-12

24.ANUSAVICE K.J., PHILLIPS R.W.: Phillips' science of dental materials, Saunders, 2003, p. 741

25.DHIR G., BERZINS D.W., DHURU V.B., PERIAATHAMBY A.R., DENTINO A.: Physical properties of denture base resins potentially resistant to Candida adhesion, J. Prosthodont. 2007; 16 (6): 465-72

26.KELLER J.C., LAUTENSCHLAGER E.P.: Porosity reduction and its associated effect on the diametral tensile strength of activated acrylic resins, J. Prosthet. Dent., 1985; 53: 374–379

27.ABOOD L.N.: Porosity of different thickness of acrylic polymerized by different methods, Al–Rafidain Dent. J., 2007; 7(2): 173–179

28.YOUNG B.C.: A Comparison of Polymeric Denture Base Materials, Glasgow, 2010, theses.gla.ac.uk/2245/01/2010Youngmsc(r).pdfý

29.RUYTER I.E., SVENDSEN S.A.: Flexural properties of denture base polymers, J. Prosthet. Dent. 1980; 43: 95–104

30.NEGRUTIU M., SINESCU C., ROMANU M., POP D., LAKATOS S.: Thermoplastic resin for removable partial dentures, Temporo Mandibular Joint, 55, nr.3, 2005, p.295

31.FALTERMEIER A, ROSENTRITT M, MÜSSIG D.: Acrylic removable appliances: comparative evaluation of different postpolymerization methods, Am. J. Orthod. Dentofacial Orthop., 2007 Mar; 131(3): 301.e 16-22

32.KOPPERUD H.M., KLEVEN I.S., WELLENDORF H.: Identification and quantification of leachable substances from polymer-based orthodontic base-plate materials, Eur. J. Orthod., 2011 Feb; 33(1): 26-31. doi: 10.1093/ejo/cjq020. Epub 2010 Jul 11

33.CHECHERITA L., BELDIMAN M.A., STAMATIN O., FOIA L., FORNA N.C., Rev. Chim. (Bucharest), 64, no.8, 2013, 864

34.ATHERTON J.D., LOVIUS B.B.J.: The advantages and disadvantages of removable appliance therapy, American Journal of Orthodontics, Vol. 62, Issue 6, December 1972, Pages 591–600

35.SINGH G.: Textbook of Orthodontics, Jaypee Brothers Publishers, 2008, p. 421-422, 571

36.JAGGER R.G., MILWARD P.J., JAGGER D.C., VOWLES R.W.: Accuracy of adaptation of thermoformed poly methyl methacrylate, J. Oral Rehabl., 2003; 30: 364-368

37.WILLERSHAUSEN B., CALLAWAY A., ERNST C.P., STENDER E.: The influence of oral bacteria on the surfaces of resin-based dental restorative materials: an in vitro study, Int. Dent. J. 1999; 49: 231–239

Manuscript received: 11.06.2013