Wettability of some dental materials

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The objective of the present study was the comparative evaluation of wettability of the surface of several types of materials (soft and hard acrylic materials, composite resins and glass ionomer cements) with current usage in dentistry, with increased frequency in prosthodontics and orthodontics, using the method of contact angle. The values registered for the dental materials analyzed varied between 35.04 (light cured glass ionomer cement, GC Fuji Plus) and 85.19 (soft acrylic material, Meliodent), pointing out the fact that the surface of the tested materials is hydrophilic. The dental biomaterials showed various value of the contact angle depending on the type of material and the way of cure. The knowledge of wettability may contribute to the understanding of some clinical aspects and to the adequate selection of materials, with positive consequences regarding the morpho-functional integration of the dental appliance.

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1. Introduction

According to World Health Organization, the health represents "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [1]. Within this frame, the oral health represents more than the health of teeth, being a part of general health, as multiple interactions may exist between them. Tooth decay, periodontitis, edentulousness, malocclusions may have locoregional negative consequences and may be associated with some systemic alterations and behavioral changes, such as lowering of self-esteem, difficulties in positively answering to the environment stimuli, decreasing of social interactions and quality of life [2-4].

The morpho-functional rehabilitation of the affected or absent oral structures can be achieved by specific dental interventions such as the ones belonging to the operative dentistry or periodontal, prosthetic and orthodontic specialties etc. The dental treatments presume most of the times the use of materials which get into a direct or indirect relation with the oral structures. Within this frame, the knowledge and estimation of biomaterials used, by clinical and experimental tests, represents an important and necessary aspect in getting a real biological integration, meaning tolerance and optimal functional integration.

In the present society, removable prosthodontic treatments and the orthodontic ones represent an important part of dental interventions [5]. Their implementation presumes the use of a great number of biomaterials, among them soft and hard acrylic materials, glass ionomer cements and composite resins. These can be used, depending on the clinical situation, for more purposes. The acrylic materials can be used to obtain the complete and partial dentures as well the removable orthodontic appliances, as well in their adaptation and improvement by tissue conditioning and soft or hard relining, for short or long term. The glass ionomer cements are frequently used in operative dentistry as a base filling or permanent filling material, as luting agent for crowns, bridges and orthodontic bands, as bonding material for brackets and tubes [6]. Taking into account their usage, sometimes for a long time, sometimes during the healing of oral structures, an optimal biocompatibility is a necessary condition, this meaning low citotoxicity and microbial loading. Also optimal mechanical features, stable in time are nedded.

Knowledge of surface wettability for different materials is important because it may be, for the dentist, a decision factor in choosing the used material, with the possibility of identifying the optimal material for the patient [7]. Wettability has a role in the adhesion phenomenon, as key element in the retention of the complete dentures, in correct relation with the oral structures, increasing the degree of satisfaction with the prosthodontic or orthodontic appliance. The material used for brackets bonding and orthodontic bands cementation is an important element for their retention, influencing the treatment outcome and duration. Both composite resins and glass ionomer cement can be used for these clinical purposes. In their case a hydrophobic character may be on advantage, namely a better resistance in time and a lower microbial loading, with a lower risk of decalcifications.

The objective of the present study was the comparative evaluation of wettability of the surface of several types of materials currently used in dentistry, with increased frequency in prosthodontics and orthodontics.

We had in view this feature by comparing soft and hard acrylic materials, composite resins and glass ionomer cements. In some cases, this feature was analyzed in the same material category, by variants with different mechanisms of cure. A better knowledge of surface wetting properties may contribute to a better understanding of some oral pathological aspects and to the adequate selection of the materials, with positive consequences regarding their morpho-functional integration.

2. Experimental procedures

2.1. Contact angle method

Contact angle (θ) represents a quantitative method of evaluation the surface wettability. It is defined geometrically as being the angle made by the liquid drop at the border of the three phases: liquid, solid and gaseous. θ is the angle formed by the solid sample surface and the tangent at the surface of the drop. Low values of the angle indicate good wettability, while the angle increases, the wettability decreases. If the contact angle is less than 90° the liquid is said to wet the solid. If it is greater than 90° it is said to be non-wetting. Contact angle is first used to appreciate the wetting characteristics, but other experimental parameters can be taken into account, such as: work of adhesion, work of cohesion, work of spreading, wetting tension. Contact angle measurements were made with the experimental appliance KSV Instrument's CAM 101, equipped with high speed digital video camera (C 200-HS; KSV – Finland). This appliance allows the measurement of the contact angle by goniometric method. Goniometry is the analysis of the shape of a drop of test liquid placed on a solid, the basic elements of a goniometer being a light source, sample stage, lens and device for image capture. KSV Instrument's CAM uses computer analysis of the drop profile in order to generate contact angle data. The software can fit the Young-Laplace equation to the shape of the drop accurately by using all of the points on the drop profile [8].

The measurements were made using as test liquid distilled water (density 0.9986 g/cm³), in the air (density 0.0013 g/cm³), at room temperature (t=20 C). There were used drops with small volume, so that the effects of distortion caused by gravitation would be at minimum level.

There were registered values of the contact angle for 45 seconds continuously, at every 5 seconds.

2.2. Dental materials chosen for tests

In order to get the proposed objects there were chosen 9 commercial products corresponding to four types of materials used in orthodontics and removable prosthodontics: hard acrylic and soft acrylic materials, composite resins and glass ionomer cements (Table 1).

Hard acrylic materials based on polymethylmethacrylat (PMMA) are the most used to make the removable dentures and the removable orthodontics appliances, as well for their relining and repairing. PMMA was one of the first materials introduced in removable prosthodontics and orthodontics. It replaced, starting with 1930, the vulcanite, being largely used nowadays too. Depending on the way of curing it is found in various forms: self cured, heat cured and light cured. These materials are found as a bicomponent product, powder and liquid and are hard at the end of cure.

Soft acrylic materials based on polyethylmethacrylat (PEMA) are used for temporary relining, for tissue conditioning, as well for functional impression. As the previous ones, they are found under the form of powder and liquid, and after the cure they remain plastic and elastic, for duration of time depending on the type of material and the commercial product. They have the advantage that they bond well to PMMA, the material out of which the dentures or overdentures are usually made.

Table 1. Products used for samples preparation, with details regarding the type of material, curing method, commercial product and producer.

Type of material	Curing method	Commercial product	Producer
hard acrylic material	self cured	*Duracryl*	*Spofa Dental*
	heat cured	*Superacryl*	
		Prothyl Hot	*Zhermack*
soft acrylic material	chemically cured	*Viscogel*	*Dentsply De Trey GMBH*
	chemically cured	*GC Tissue Conditioner*	*GC Europe*
composite-based resins	light cured	*Resilience*	*Ortho Technology*
	chemically cured	*Resilience*	
glass ionomer cement	light cured	*GC Fuji Ortho LC*	*GC Europe*
	self cured	*GCFuji PLUS*	

Bis GMA composite resins are largely used in dental medicine for various medical dental procedures. They are used as esthetical materials in the restorations of tooth-decay processes, as sealant material, as adhesives for bracket bonding. For the analysis we chosen two types of composite resins frequently used in orthodontics for brackets bonding, different depending on the way the cure is achieved: more precisely self and light cured materials. The commercial products chosen include a paste, a bonding and a phosphoric acid used for demineralization. In this class of materials, the adhesion to the enamel it is obtained by retention using the enamel microcavities present after the etching phase. The method of application is similar for both variants of products. The surface of enamel is demineralised with the etching gel in the kit, then washed and dried. The bonding is applied on the etched enamel surface and on the bracket's base. After that, on the prepared surface this layer is softly "blown" with the air spray of the unit, at a low pressure. The adhesive resin is then applied on the base of the bracket

and after that, the bracket is fixed in the wanted position on the tooth surface. For the self cured materials the hardening is achieved after applying pressure to the bracket and for light cured resins by fotopolimerization method. An advantage of the light cured materials is the longer time of handling and positioning of the respective appliance, curing taking place after fotopolimerisation.

Glass ionomer cements are used in operative dentistry, for base base fillings and final fillings, in fixed prosthodontics (crowns and bridges cementation) and orthodontics (adhesive for bracket bonding and cement for bands). After hardening, the elements of cement can become soluble in neutral liquids such as saliva in our mouth, but only in a small quantity. At a certain degree the flour released by glass ionomer cement has a protective role in decay formation. The released flour penetrates the neighboring dental tissue interacting with hydroxiapatita, forming fluoro- hydroxiapatite and thus it has anticaries effects. In order to get the samples, two types of glass ionomer cement were chosen being different by the way the cure is achieved: self and light cured cements. This aspect is important especially from the clinical point of view, with implication during the maneuver of material application. Glass ionomer cements are found as a biocomponent system: powder (alumino-silicate glass) and liquid (poliacrylic acid liquid). The material is best prepared by mixing the components following the producer`s instructions regarding the proportions.

2.3. Samples preparation

For each product there were produced 5 specimens, getting a total of 45 samples. In order to get samples with smooth, plane surface, compatible with the chosen analysis method, there were prepared according to the instructions of the producer and then put on a microscope slide.

In order to prevent the study errors the masking of the laboratory worker who analyzed the samples was used. Thus the specimens were codified and the person who made the contact angle measurements did not know what material he was analyzing.

2.4. Data analysis

The data analysis was done using StataIC statistical software version 11. The values for the contact angle were reported as mean value and standard deviation (SD). Nonparametric test Kruskal-Wallis was used for variance by ranks analysis between the contact angle values corresponding to the analyzed materials. After that, Mann-Whitney test was applied between each pair of groups for intergroup comparison, performing multiple post hoc comparisons.

3. Results

The values recorded for the analyzed dental materials varied between 35.04º and 85.19º saying that the surface of the materials is hydrophilic (Table 2). The drop volume had values of 5.32 µÅ (SD 2.05). For both composite resin and glass ionomer cement, the light cured commercial products were more hydrophilic than the self cured ones. The acrylic materials had higher contact angle values than the previous ones. Within this frame, the self cured hard acrylic materials and the soft ones were more hydrophilic than the heat cured ones.

Table 2. Contact angle values (mean, standard deviation) for the materials analyzed together with comparison between pairs of materials by Mann-Whitney test.

Commercial Product		Contact angle values		Comparison between materials								
		mean	*SD*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Duracryl	*1*	75.97°	3.77									
Superacryl	*2*	84.81°	1.14	*								
Prothyl Hot	*3*	85.19°	1.74	*	*ns*							
Viscogel	*4*	77.34°	3.87	*ns*	*	*						
Tissue Conditioner	*5*	76.44°	3.67	*ns*	*	*	*ns*					
Resilience (light-cured)	*6*	48.45°	3.68	*	*	*	*	*				
Resilience (self-cured)	*7*	64.91°	3.40	*	*	*	*	*	*			
Fuji Ortho	*8*	35.04°	0.81	*	*	*	*	*	*	*		
GC Fuji PLUS	*9*	56.59°	3.52	*	*	*	*	*	*	*	*	

SD - standard deviation
**- materials that were significant at α = 0.05 significance level*
ns - not significant

By Kruskal-Wallis nonparametric test we observed that ranks were significantly different between the 9 commercial products analyzed ($p<0.001$). There were made post hoc comparisons to notice if there are differences between the contact angle values between commercial products belonging to the same category of materials, but with a different mechanism of cure. In our study there are statistically differences between the materials with different cure mechanism, namely self and light cured cements and composite resins, self cured acrylic resins and heat cured acrylic materials. Superacryl and Meliodent, commercial products belonging to the same category of materials and with the same cure mechanism, did not show statistically important

differences regarding the contact angle value. The situation was similar for Tissue Conditioner and Viscogel (Table 2).

4. Discussion

The present study had in view the comparative evaluation of wetability by measuring the contact angle for several types of materials largely used in dental medicine, especially in prosthodontics and orthodontics, in order to understand their behavior and thir clinical indications.

A good wetability represents in the case of the complete denture device a favorable aspect for obtaining the retention during functioning. The thin saliva film which appears between the basis of the prosthetic appliance and the oral mucosa creates retaining forces having a role in the adhesion, a phenomena that contributes to the retention of the device. A good wetability is usually associated with a hydrophobic character [9]. These represent useful features because water absorption may have positive implications on the dimensional stability of the dentures by countering the contraction which appears after curing. Also it helps in the intraoral adaptation by lowering the friction between the appliance and mucosa, increasing the patient's comfort. If this excels standard values it may produce dimensional modifications which might endanger the clinical success and the denture longevity. At the same time we can say that in the patients with hiposialia there was found a lower tolerance for dentures and in their case it is advisable to choose a material with a lower contact angle for providing a better comfort [10]. Many times, dental treatments that presumes the use of appliances made of acrylic materials are addressed to either aged people, with a decreased immunity, susceptible to infections, either children, in both case, frequently, the oral hygiene and cleaning of the appliance being deficient and thus the treatment may became a risk factor in the appearance of stomatitis [11]. The increased hydrophilic character is also seen as a disadvantage because it offers optimal conditions for the adherence and development of microbial germs, favoring the apparition of the biofilms on their surface [12]. Also, porosity and hydrophilic character of the acrylic resins are elements that can be correlated to the misbalance appeared in the microbiocenosis of the oral cavity, offering optimal conditions for the adherence and development of germs (an etiologic agent frequently incriminated is Candida Albicans which sticks to the acrylic material due to its fibrillar surface layer). The hydrophilic character contributes also to the lowering of the mechanical resistance associated in time with a higher risk of appliances fractures. But hydrophilic character and the fact that after cure the dentures are kept in water helps to remove remaining monomers, in consequence lowering the citotoxic effect. In the saliva there can be present various food pigments (from coffee, tobacco), due to the hydrophilic character and porosity of the materials, in time, discoloration may appear, with aesthetics implications and negative consequence on the psychological comfort of the patient. In orthodontics glass ionomer cements are used especially for fixing the bands and bonding the brackets. In the course of time, due to the hydrophilic character of the material and due to the fact that solubilization can take place, there may appear a space which represents a retention zone for the dental plaque, becoming an etiologic agent for decay and periodontitis, contributing to a higher risk of bracket debonding. For cements and composite resins, the volume of the contact angle is very much influenced by the cure mechanism. The light cured materials, compared to the self cured ones have the advantage that gives the practitioner more time to do a precise positioning of the appliance with proper removal of the extra material, as the time for handling is longer. The disadvantage is the fact that, for a proper cure, the light source must get to the level of the material. The material must not be very thick as the profusion of light curing is important (for hardening the light must not meet impermeable obstacles, such as the metal, materials that frequently orthodontic appliances are made from). By our results, we can say that the glass ionomer cements have a better wettability than the composite resins. So, when the materials have the same clinical indication, namely bonding of orthodontic brackets, in order to prevent caries apparition as orthodontic treatment complication, in high risk patients the dentist may choose the composite material, which is more hydrophobic and theoretically predispose less to plaque accumulation. So, by a good knowledge of the feature of the materials together with the particularities of each case the dentist can chose the best therapeutic solution individualized for each patient, delivering a medical intervention with minimum side effects [13].

Regarding the contact angle values identified in the scientific literature for the types of materials analyzed in this research, the studies are few and the results are not uniform. Besides, most of them analyze commercial products that are mostly different from those in our study. That is why we can say that the differences between the values we found can be associated also with the presence of different commercial products. Hilgenberg, in a study on self cure hard acrylic materials, got values of contact angle close to those in our study (63.3 -68.3) [14]. Jin, analyzing the materials used for relining finds values of contact angle about 10 lower for heat cured acrylics (75.356) and 10 higher for soft acrylic materials (85.625) [15]. Nishoka gives values between 68.7 and 77.4 for the polished heat cured acrylics (commercial product ACRON, GC, Tokyo, Japan). But the process of polishing, as the author himself underlines, in case of acrylic resins decreases the rugosity and consequently the contact angle decreases [16]. Zeiss, testing the materials used for dentures' base and relining, finds lower values of the contact angle for the soft acrylates (59.9 - 69.9) and higher for the hard ones (71.8 - 77.3). From the self cure hard materials, there were chosen two, wetting values being intermediate to the heat cured materials from our study (73.4 and 75) [17]. In another study, Zissis finds values of the contact angle of the soft materials for relining lower than of the hard ones [18]. Watter also finds acrylic materials as having a better wettability than the silicone

ones [19]. Satou finds for chemically cured composite resins based on Bis-GMA values of 64.4°-65.9° [20]. Namen find for light cured resins contact angles of 79 and 71 [21]. Moshvarenia finds for GC Fuji IX, self cure cement, a close value (57) as ours for GC Fuji PLUS, the two materials belonging to the same producer [22]. In a study made by Namen on light cured materials of this type, the values of the contact angle are much higher [21].

Taking into account the great variety of commercial products existing, in the future we plan to analyze more commercial products belonging to the same type of material by the contact angle method, to see if similar behavior can be observed. Also, this feature should be tested after a period of time after the samples are introduced in the artificial saliva, to create similar condition to the oral environment.

5. Conclusions

At the end of the present study, according to research findings, we can affirm that:

1. All dental materials analyzed have a contact angle lower than 90 , showing a hydrophilic character.
2. The change of cure method is accompanied by a change of wetting characteristics. Self cured acrylic materials showed a smaller value of the contact angle compared to the heat cured ones. Self cured resins and cements had higher values of the contact angle compared to the light cured ones.
3. The self cured hard acrylic materials and soft relining one (used for tissue conditioning) showed values of contact values lower than the hard heat cure ones, having the largest contact angle values. These results explain the increased dentures' retention, stability and patient's comfort after relining, which depend directly on the lubricating effect of saliva and denture's surface properties. At the same time, this behavior of the acrylic materials used in soft or hard relining explains the apparition of the stomatitis related to them.
4. As for the materials used in fixed orthodontics, for the bracket bonding, it is better to use a material as hydrophobic as possible, not to favor the microbial adherence, which can lead to complications like tooth decay. According to our results, in this case the best one is a self curing acrylic resin.
5. The dental biomaterials showed various value of the contact angle depending on the type of material and the way of cure. The knowledge of wettability may contribute to the understanding of some clinical aspects and to the adequate selection of materials, with positive consequences regarding the morpho-functional integration of the dental appliance.

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