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Estimation of Changes in Some Hydrodynamic Characteristics of Glass Ionomer Cements for Non-removable Structures Fixation

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Abstract: The increase of glass ionomer cement operational and technological characteristics to fix non-removable structures plays an important role in orthopedic treatment reliability improvement. The purpose of the study was to perform a comparative evaluation of the film thickness and the fluidity of popular glass ionomer cements: Fuji 1 (GC, Japan), Meron (VOCO, Germany), Polyacrylin (TechnoDent, Russia). The study revealed the dynamics of film thickness change and the fluidity of cements with delayed loading 60, 90, 120, 150, 180 and 210 sec after the commencement of mixing under the powder/liquid ratio recommended by the manufacturers. Throughout the study, the smallest film thickness was demonstrated by the "Polyacrylin" cement and the greatest fluidity was found in the "Fuji 1" cement.

Key words: Fluidity, film thickness, hydrodynamics, glass ionomer cements, cement removal, fixed structures

INTRODUCTION

Widely implemented preventive measures and developed remineralizing compounds did not reduce significantly the number of patients suffering from the complications of carious disease (Kuzmina *et al*., 2014). This circumstance causes the development of a more severe pathology, leading to the removal of teeth among children and adults (Saksena *et al*., 2014; Bhopal and Ameerally, 2016).

One of the most popular approaches to the rehabilitation of patients with the secondary partial adentia is the restoration of occlusal ratios with non-removable structures (Lebedenko *et al*., 2015). Clinical experience shows that this approach is far from a perfect one and complications are possible within a favorable prognosis, determined by an occlusive load (Bragina *et al*., 2015). Numerous studies are devoted to the impact of occlusive load and the development of complications associated with it in which among other reasons, the problem of supporting tooth tissue overload (Kopytov, 2007) and the separation of a covering coating (Mikheeva and Bolshakov, 2014) is considered.

One of the most common complications is the unsealing of non-removable structures (Sadykov *et al*., 2015). According to a number of research, the reduction of their amount is possible due to the removal of various types of "contamination" from the surface of a tooth stump (Camilotti *et al*., 2013) and due to the increase of cement operational and technological characteristics (Polyanskaya *et al*., 2015). The demonstration of cement characteristics exceeding standard requirements by producers is welcomed by consumers. At the same time, the number of unsealing remains a very common complication. Since, the main function of dental cements is the creation of a reliable hermeticism in the region of a crown which opposes the action of the oral fluid then, we consider it is necessary to isolate a group of hydrodynamic parameters in the series of cement operational and technological characteristics. It is reasonable that these parameters include the thickness of a film and fluidity.

Purpose of the study: The comparative evaluation of a film thickness and the fluidity of dental glass ionomer cements to fix non-removable structures "Fuji 1" (GC, Japan), "Meron" (VOCO, Germany), "Polyacrylin" (Technodent, Russia).

Objectives of the study:

- To estimate the film thickness of glass ionomer cements
- To determine the fluidity of glass ionomer cements

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MATERIALS AND METHODS

The film thickness test was carried out in accordance with ISO 9917 and ISO 9917-2 at the temperature of 23±1°C and a relative humidity of 60±10%. The fluidity was determined according to ISO 6876 at the temperature of 23±2°C and a relative humidity of 50±5%.

In order to solve the first problem, the thickness of two optically flat glass plates stacked together (each is 6.0 mm thick) was verified by an electron micrometer MKП-25 0.001 with the error of 1 µm. The upper plate was removed and about 0.1 g of mixed cement was placed in the center of the lower plate. Then, the cemented plate was placed on the base of a load device, so that, the cement sample was placed in the center of the load application. The cement was covered with the second glass plate in such a way that the ratio of the plates corresponded to the position of their thickness initial measurement. The load of (150.0±2) N was applied perpendicular to the center of the plates. These actions were carried out 60, 90, 120, 150, 180 and 210 sec after the beginning of component mixing. About 10 min after the start of the load application, the cemented plates were removed from the load device and the total thickness of the cement plates and films was measured. The difference between the thickness of the plates with a film of cement and without it was considered as the thickness of the film. According to ISO conditions, the film thickness of the glass ionomer cement should not exceed 25 µm. The measurement of the film thickness at each exposure from the start of mixing to the application of the second glass plate was carried out five times for each material.

The solution of the second problem. Using a dispenser, 0.075 mL of material was placed on a glass plate. About 60, 90, 120, 150, 180 and 210 sec after the commencement of mixing, the material was covered with a second glass plate and the load of 2.5 kg was applied using a load device. About 10 min after the beginning of mixing the load was removed. The print of the material had the shape of an ellipse as a rule. The largest and the smallest diameters of an ellipse were measured their mean value was determined. If the difference between a larger and a smaller diameter exceeded 1 mm, the attempt was not considered as a correct one. Within the framework of each material study, the procedure was carried out five times at each exposure. The obtained data were summarized, mean values were calculated which was considered to be the indicator of fluidity. The fluidity of the material was determined according to the conditions of ISO 6876:1986. The procedure was used to obtain the comparative data by flow but the prerequisite was to obtain a print with an even edge.

RESULTS AND DISCUSSION

The exposure of the load 60 sec after the start of mixing on the glass ionomer cement “Fuji 1” led to the development of the film with the thickness of 13.76±0.84 µm, “Meron”-15.24±0.73 µm. The smallest film thickness-11.52±0.61 µm was demonstrated by “Polyacrylin”.

When the load was applied 90 sec after the beginning of mixing, the thickness of the film “Fuji 1” increased by 5.55% and made 14.52±0.47 µm as compared to the first measurement. The thickness of Meron cement film increased by 2.42% and made 15.61±0.87 µm. The best indicator of 12.03±0.54 µ with the increase of 4.43% was demonstrated by “Polyacrylin”.

The loading after 120 sec showed that the thickness of “Fuji 1” cement film increased by 9.3% and was equal to 15.04±1.12 µm, the Meron cement by 7.15% which made 16.33±1.09 µm, the cement “Polyacrylin” -12.72±0.83 µm with the increase of 10.41% as compared to the first measurement.

After the exposure increase up to 150 sec due to the end of the working time, the thickness of the Fuji 1 cement film increased sharply by 50.44% up to 20.7±2.66 µm. The thickness of the Meron cement film increased by 26.9%, up to 19.34±2.31 µm. The smallest film thickness of 13.84±1.5 µm was demonstrated by “Polyacrylin”. At the end of the working time, the increase was 20.14%.

About 3 min later, the index of the cement “Fuji 1” film thickness increased by 120.86%, up to 30.39±4.05 µm which exceeded the GOST value. “Meron” cement with the greatest working time demonstrated the film thickness equal to 25.72±3.4 µ with the increase by 68.77%. The thickness of “Polyacrylin” cement film increased by 155.73% and reached 29.46±3.72 µm.

When the load was applied 210 sec after the beginning of mixing, the thickness of “Fuji 1” cement film was 45.68±5.33 µm, the Meron cement 57.49±5.68 µm with the increase of 231.98 and 277.23%, respectively. The increase of the “Polyacrylin” cement film thickness was 284.98% and corresponded to the film thickness of 44.35±4.93 µm. The measurement carried out during this time interval showed that the film thickness for compared cements exceeded ISO requirements. The thickness of glass ionomer cement film, depending on the exposure time which passed, since, the commencement of the component mixing prior to the load application is presented in Table 1.

The best fluidity with strict adherence to the producer recommendations was demonstrated by glass ionomer cement “Fuji 1” 36.74±3.53 mm-60 sec after the start of mixing. The fluidity of “Meron” and “Polyacrylin” cements was 30.91±3.87 and 35.56±3.81 mm, respectively.

Table 1: Film thickness of glass ionomer cements (μm)

Material	Parameters according to instructions		Time from the beginning of mixing (sec)										
	Working time (sec)	Hardening time (sec)	60	90		120		150		180		210	
			μm	μm	%	μm	%	μm	%	μm	%	μm	%
"Fuji 1"	120	270-300	13.76 ±0.84	14.52 ±0.47	5.55*	15.04 ±1.12	9.30*	20.70 ±2.66	50.44*	30.39 ±4.05	120.86*	45.68 ±5.33	231.98*
"Meron"	180	300-420	15.24 ±0.73	15.61 ±0.87	2.42	16.33 ±1.09	7.15*	19.34 ±2.31	26.90*	25.72 ±3.40	68.77*	57.49 ±5.68	277.23*
"Polyacrylin"	120-150	360-420	11.52 ±0.61	12.03 ±0.54	4.43*	12.72 ±0.83	10.41*	13.84 ±1.50	20.14*	29.46 ±3.72	155.73*	44.35 ±4.93	284.98*

*The change of film thickness is reliable at p = 0.05 as compared with the primary data

Table 2: The fluidity of glass ionomer cements (mm)

Material	Parameters according to instructions		Time from the beginning of mixing prior to the positioning in a load device (sec)										
	Working time (sec)	Hardening time (sec)	60	90		120		150		180		210	
			μm	μm	%	μm	%	μm	%	μm	%	μm	%
"Fuji 1"	120	270-300	36.74 ±3.53	35.97 ±3.71	2.10	34.40 ±2.34	6.37*	32.95 ±2.87	10.32*	30.11 ±2.50	18.05*	27.63 ±2.19	24.80*
"Meron"	180	300-420	30.91 ±3.87	30.12 ±2.14	2.56*	26.60 ±2.63	13.94*	24.53 ±2.75	20.64*	22.75 ±2.72	26..40*	18.33 ±4.46	40.70*
"Polyacrylin"	120-150	360-420	35.56 ±3.81	35.19 ±3.57	1.04	33.63 ±2.32	5.43*	30.92 ±2.61	13.04*	28.77 ±2.04	19.09*	24.34 ±2.75	31.55*

*The reduction of fluidity is reliable at p = 0.05 as compared with the primary data

In the case of plate alignment and load application 90 sec after the commencement of mixing, the fluidity of "Fuji 1" cement decreased by 2.1% and corresponded to 35.97±3.71 mm as compared to the previous measurement. The fluidity of "Meron" cement decreased by 2.56% and made 30.12±2.14 mm. The fluidity of "Polyacrylin" cement did not change and made 35.19±3.57 mm which is comparable to the fluidity of the cement "Fuji 1".

After 120 sec exposure and subsequent loading, the fluidity of the Fuji 1 material decreased by 6.37% and reached 34.4±2.34 mm. The greatest decrease in fluidity by 13.94% down to the value of 26.6±2.63 mm was demonstrated by "Meron" cement. The flow index of "Polyacrylin" cement decreased by 5.43% and amounted to 33.63±2.32 mm. In this case, the fluidity of the cement "Polyacrylin" does not differ for certain from the fluidity of "Fuji 1".

The application of the plates and the loading after 150 sec revealed a better fluidity of "Fuji 1" cement at 32.95±2.87 mm with the increase of 10.32%. The fluidity of "Meron" cement decreased by 20.64%, down to 24.53±2.75 mm. The fluidity of the cement "Polyacrylin" decreased by 13.04%, down to 30.92±2.61 μm.

About 180 sec after the fluidity index of "Fuji 1" cement decreased by 18.0% and corresponded to 30.11±2.5 mm. "Meron" cement with the greatest working time, demonstrated the fluidity of 22.75±2.72 mm with the value decrease by 26.4%. The fluidity of the cement "Polyacrylin" decreased by 19.09%, down to the value of 28.77±2.04 mm.

After the loading of plates 210 sec after the commencement of mixing, the fluidity index of "Fuji 1" cement decreased by 24.8% and made 27.63±2.19 mm. The least fluidity was detected in Meron cement 18.33±4.46 mm with the decrease of 40.77%. The glass ionomer cement "Polyacrylin" had the reduction of fluidity index by 31.55% from the initial level and made 24.34±2.75 mm. The fluidity of glass ionomer cements, depending on the exposure time, that passed, since, the commencement of component mixing before the application of the load is presented in Table 2.

An important condition which determines the clinical effectiveness of glass ionomer cements to fix non-removable structures is the index of film thickness-the layer of material which fills the space between a crown and a tooth stump which to some extent determines the period of a fixed structure operation.

Since, the volume between a tooth stump and a crown should be filled without voids, the requirement is introduced to ensure the clinical effectiveness of glass ionomer cements. This requirement regulates the maximum permissible film thickness equal to 25 μm. The technological breakthrough in the grinding of the cement "Polyacrylin" glass filler allows to reduce the film thickness of the mixed material by 30-50% from the standard requirements.

The clinical significance of the technological characteristic "film thickness" is explained by the features of glass ionomer cements to a rapid increase in viscosity. As soon as the curing process begins, the film thickness is increased and its fluidity is decreased drastically. The development of a "thick" film leads to the reduction of cement clinical effectiveness. In this case, several options are possible. First of all, in the process of a prosthesis application with the presence of a gap between a crown and a stump less than the thickness of a developed film it is possible to violate its integrity with the development of voids which reduces adhesion, increasing the probability of a prosthesis unsealing. The adhesion of glass ionomer cements is explained by the chemistry of ionic interaction between the carboxyl groups of polyacrylic acid and the calcium ions of tooth structures (Consani *et al*., 2003). Secondly, with the application of long prostheses, a "thick" film can interfere with a proper positioning of a structure. In this case, a physician is confronted with a clinical contradiction, since, the more a design corresponds to a tooth stump, the more difficult to leave a crown volume for an excess cement (Wang *et al*., 1992).

An incorrect positioning leads to the appearance of gaps between a crown ledge and edge which can lead to acid erosion and the dissolution of cement, the development of retention points for bacteria, etc. Studies showed that a qualitatively manufactured crown and the use of cement forming a film with the thickness of 25 μm may produce gaps between the crown and ledge and edge with the width of up to 50 μm during the application of a prosthesis (Cardoso *et al*., 2008).

In addition to film thickness, fluidity is an important hydrodynamic characteristic of fixing materials. Evaluating the operational-technological characteristics of glass ionomer cements, it can be asserted that the indicator "fluidity" determines the index "film thickness" in some sense. At the same time, the fluidity of the material determines the clinical features of cement more widely (Tsimbalistov *et al*., 2015, 2016). In addition to the ability to fill the space between a tooth stump and a prosthesis without voids, the "fluidity" characteristic determines the cavity dimensions in the hard tissues of teeth and the surface of a crown into which the material penetrates. However, the ISO for fixing cements has no need to evaluate the "fluidity" parameter. For this reason, in order to evaluate this parameter, we used the fluidity determination procedure in accordance with ISO 6876:1986 "Dental materials for root canal filling".

The fluidity of the material decreases rapidly after the end of mixing, so, it is recommended to apply a ready-made mixture to the crown walls and to a stump immediately, since, a thicker compound is characterized by a thicker film which can lead to the voids between the dentin and the crown material.

It is especially, important to distribute time correctly during a fixed prosthesis mounting with a large number of supporting teeth during which significant amounts of material components are mixed. In this case, it is necessary to consider two aspects. First of all by spending time close to or slightly exceeding the working one. A doctor, striving to achieve the preservation of the prosthetic surface, makes a great effort, putting a crown on a ledge. The result of such actions is the violation of a glass ionomer matrix structuring and the decrease in the strength characteristics of cement, its adhesion with all the consequences. Secondly, understanding the emerging problem, a dentist instructs to increase the amount of liquid (reduce the amount of powder) to prepare a mixture. This indication is not devoid of household logic but it can lead to a gross violation of the cement curing mechanism, because during the maturing process of cement, the water retained in it partially hydrates the unreacted particles of a glass powder, forming a silica gel in the form of a shell which contains the remaining glass particles. Thus, cured cement has a characteristic structure containing the particles of unreacted powder in a silica gel shell, distributed in a matrix of calcium and aluminum polysalts (Hill and Lott, 2011). The unreacted molecules of acids can irritate periodontal tissues. Thus, violating the manufacturer's recommended powder/liquid ratio to increase a mixture fluidity in order to ensure the restoration of the prosthetic plane, a dentist worsens significantly the operational and technological characteristics of glass ionomer cements.

CONCLUSION

"Polyacrylin" cement fixing the non-removable structures is reasonable to use in case of certainty that the fixation of a non-removable structure will end after 150 sec from the beginning of a material mixing, because at this exposure "Polyacrylin" forms a film of the smallest thickness equal to 13.84±1.5 M in comparison with the tested cements.

If according to a doctor's opinion, the fixation procedure will last more than 150 sec, the choice of cement for fixation can be based on subjective factors, since, 180 sec after the beginning of mixing the thickness of a film among all cement studied has the boundary value from the value recommended by ISO.

The determination of glass ionomer cement fluidity to fix non-removable structures during the period from 60-180 sec after the commencement of mixing is an important indicator and there is a need to introduce this indicator into the normative and technical documentation (ISO).

"Meron" cement with the greatest working time (180 sec) in the series of materials under study, shows a low fluidity 210 sec after the commencement of mixing which imposes some restrictions on the use of this cement during the fixation of non-removable large-scale structures. Cement "Fuji 1" and "Polyacrylin" maintain the level of fluidity for a long time.

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