ORIGINAL ARTICLE

COMPARATIVE ANALYSIS OF ENDURANCE CEMENTS FOR THE FIXATION OF NON-REMOVABLE ORTHOPEDIC CONSTRUCTIONS UNDER THE ACTION OF CYCLIC COMPRESSION

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ABSTRACT

The aim: To conduct studies of the physical and mechanical properties of cements for fixation, namely the duration of cement samples under cyclic compression.

Materials and methods: We have conducted a study of 6 cements for permanent fixation of fixed structures of dentures. To study the duration of cements under cyclic compression, a special stand was used, which allows testing samples for cyclic compression with a load frequency of 5.4 Hz or 324 cycles per minute and an increase in compression in a cycle from 10 to 100 kg/s.

Results: Comparative analysis of the mechanical properties in compression of dental cements for permanent fixation showed that the obtained deformation curves differ significantly in each of the cement samples used in the study.

Conclusions: The results of the study of the physical and mechanical properties of cements indicate that the most optimal complex of properties is possessed by the zinc-phosphate cement Unitsem and glass ionomer cements Cemion and Fuji I. This is most clearly confirmed when studying the duration of cement samples under cyclic compression, which simulates a real situation.

KEY WORDS: Dental Cements, dental crowns, fixation, cyclic compression

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INTRODUCTION

The frequency of using fixed dentures is distributed as follows: 37.7% – single crowns, 29.4% – bridges, 1.45% – pin teeth, 0.7% – inserts [1, 2]. The average term of use of fixed orthopedic structures is 5-6 years, of which bridges are 4-5 years, single crowns are 6 years [3, 4].

An important reason for the short use of fixed prostheses is the cementation of crowns, which accounts for 21% of all complications [5-7].

There are many reasons for short-term use of fixed dentures. The leading causes that lead to complications and dysfunction and cementation of fixed orthopedic structures are as follows:

1) low crowns of abutment teeth due to improper preparation;
2) violation of the prosthesis manufacturing technology and, as a result, loose fit of the crown edges to the tooth neck;
3) prosthesis breakage;
4) violation of the rules of mixing fixing cement;
5) violation of fixation technology [8-10].

The main factors that affect the effectiveness of fixation of fixed dentures include: the correct preparation of the abutment teeth, the quality of the materials used, as well as adherence to the rules and technology of fixation [11-13].

According to the requirements, cements for fixation must be sufficiently resistant to the influence of the oral environment and provide a strong bond through mechanical adhesion and adhesion [14, 15].

A wide variety of cements are used in modern dental practice. However, there is not enough information in the literature on the effect of cement on the tissues of the oral cavity, therefore, we consider it expedient to study the biological effects of various types of cements on the tissues of the oral cavity, especially on the tissues of the tooth and the body as a whole.

THE AIM

The aim of the research was to conduct studies of the physical and mechanical properties of cements for fixation, namely the duration of cement samples under cyclic compression.

MATERIALS AND METHODS

This study was conducted at the orthopedic dentistry department I. Horbachevsky Ternopil National Medical University, Ukraine, and was approved by the ethics committee of the I. Horbachevsky Ternopil National Medical University.

A study was conducted on 6 cements for permanent fixation of non-removable denture structures. Of these, 2 are zinc-phosphate cements: "Adhesor Fine" ("SpofaDental", Czech Republic) and "Unitsem" ("VladMiva", Russia); 2 polycarboxylate cements "Belokor" ("VladMiva", Russia); "Adhesor Carbofine" ("SpofaDental", Czech Republic); 2 glass ionomer cements: " Cemion F" (VladMiva, Russia) and "Fuji I" (GC, Japan).6 batches of samples (3 samples per batch) were made for testing. The sample is a removed tooth with a solid metal crown fixed on it by means of the investigated cements.

To study the duration of cements under cyclic compression, a special stand was used, which allows testing samples for cyclic compression with a load frequency of 5.4 Hz or 324 cycles per minute and an increase in compression in a cycle from 10 to 100 kg/s.

For the study, we selected three levels of maximum compression forces 25±1 kg/s, 40±1 kg/s, 60±1 kg/s, which determined the cyclic duration of the samples. The duration is expressed in the number of cycles that the sample withstands until failure at the selected load levels. For the destruction of the sample, the loss of the cement-containing properties was taken, which is expressed in a slight displacement of the crown relative to the tooth when a weak static force (~ 2 – 3 kg) is applied to detach the crown from the tooth.

During the test of the sample, the load was interrupted to determine the level of destruction. For this, the sample was removed and examined under an MBS-9 microscope the state of the cement film between the edge of the crown and the tooth. After that, holding the tooth, an attempt was made to recover the crown using a metal hook and a dosed load. The tests were stopped and the number of fracture cycles was recorded at the moment when the crown was displaced relative to the tooth. Checking the integrity of the connection of the crown with the tooth was observed under a microscope in the following mode: up to 10^4 cycles for every thousand cycles; $2x10^4$ – every two thousand; to $5x10^4$ – after five thousand and further to destruction or termination of the test every ten thousand cycles.

RESULTS

The obtained deformation curves differ significantly for different types of cements that were used in the experiment. As a result of the study, the following results were obtained.

Fracture is fragile in zinc-phosphate cements "Adhesor Fine" and glass ionomer cement "Fuji I", they do not exhibit plasticity, their deformation curves have only a linear elastic section.

The investigated polycarboxylate cements "Belokor", "Adhesor Carbofine" and glass ionomer cement "Cemion F" shows significant plasticity with a pronounced yield point, which corresponds to the beginning of deviation from the linear section.

Further, the deformation pressure increases, and when it reaches a maximum, plastic deformation can be several percent. The pressure drop during the subsequent plastic deformation is associated with the formation of stable shear bands, which arise due to the destruction of crosslinking in the corresponding slip planes.

As a result, these processes lead to an increase in the cross-section of the sample (the so-called barrel-shaped sample is observed), which leads to the need to increase the deforming forces to support plastic deformation.

"Unitsem" zinc phosphate cement occupies an intermediate position between the two types of deformation curves described above. In contrast to zinc-phosphate cement "Adhesor Fine" and glass ionomer cement "Fuji I", the curve created as a result of the experiment shows a transition from elastic deformation to the stage of plastic deformation. However, upon reaching plastic deformation within a few percent, destruction of the sample occurs (Table I).

For "Adhesor Fine", "Fuji I" and "Unitsem", this value was determined as the pressure at the time of destruction of the sample, and for "Belokor", "Adhesor Carbofine" and "Cemion F" – as the pressure at the maximum of the deformation curve. It is seen that all these values are in the range of 800-1600 kg/cm^2.

Analysis of the compressive strength data for all studied cements showed that for "Adhesor Fine", "Fuji I", and

Table I. Kinds of cements and their strength limits (M+m)

№	Name of cements	Strength limit (M+m)
1	"Unitsem»	1030 ± 40
2	"Adhesor Fine»	1590 ± 60
3	"Belokor»	840 ± 40
4	"Adhesor Carbofine»	820 ± 30
5	"Cemion»	1360 ± 50
6	"Fuji I»	1210 ± 50

Table II. Endurance indicators of cement samples under cyclic compression

№	Name of cements	P_{max}(H)		
		250	400	600
1	"Unitsem»	$(9\pm1)\times10^8$	$(1\pm0,14)\times10^7$	$(9\pm1)\times10^5$
2	"Adhesor Fine»	$(4\pm0,48)\times10^5$	$(1\pm0,14)\times10^5$	$(3\pm0,26)\times10^4$
3	"Belokor»	$(7\pm0,69)\times10^5$	$(1,5\pm0,16)\times10^5$	$(3,5\pm0,41)\times10^4$
4	"Adhesor Carbofine»	$(12\pm1,18)\times10^5$	$(2\pm0,38)\times10^5$	$(4,5\pm0,51)\times10^4$
5	"Cemion»	$(30\pm3,12)\times10^5$	$(3,5\pm0,41)\times10^5$	$(5\pm0,53)\times10^4$
6	"Fuji I»	$(1\pm0,14)\times10^8$	$(5\pm0,53)\times10^6$	$(3,5\pm0,41)\times10^5$

"Unitsem", this value was determined as the stress at the moment of sample failure, and for "Belokor", "Adhesor Carbofine", and "Cemion F", as the stress at the maximum of the deformation curve.

Thus, all the studied cements have rather significant parameters of strength, but the presence of plastic deformation in some materials suggests that it is polycarboxylate cements that should have higher functional properties. Due to the fact that the load in bridges is greater than in single crowns, zinc phosphate and glass ionomer cements should be used when fixing them.

In the course of the study, we established the endurance indicators of cement samples under cyclic compression. "Adhesor Fine" zinc phosphate cement had the lowest duration. The longest was the sample of zinc-phosphate cement "Unitsem", glass ionomer cements "Cemion F" and "Fuji I" have satisfactory performance, slightly lower performance in polycarboxylate cements "Belokor" and "Adhesor Carbofine" (Table II).

A clear idea of the cyclic strength of the tested samples is given by the so-called Wehler curves – the dependence of the amplitude load on the number of cycles N that the sample withstood under a given load.

In double logarithmic coordinates, such dependences, as a rule, have a linear character, while, naturally, with a decrease in the load, the number of cycles to failure increases.

Specimen duration is determined by properties such as cement strength, adhesion of cement to tooth and artificial crown.

DISCUSSION

Comparative analysis of these properties shows that the greatest duration, that is, the best functional properties are those cements that, on the one hand, do not exhibit brittle properties, and, on the other hand, have the best adhesive characteristics[5].

Failure of model specimens under cyclic loading can occur due to the loss of bond between the cement and the artificial crown or tooth, as well as a result of the destruction of cement.

For brittle cements, fracture is possible even at low loads and a small number of loading cycles due to possible large overvoltages near inevitable defects in the cement layer (cracks, cavities, etc.).

For cements that are plastic, this hazard can be largely reduced by plastic relaxation, which relieves the specified overstress and provides a longer duration.

CONCLUSIONS

The results obtained for the duration of cement samples under cyclic compression showed that glass ionomer cement "Fuji I" has the highest value (9×10^5H), while "Adhesor Fine" has the lowest ($3,5\times10^5$H), which is obviously related to their chemical composition, while polycarboxylate and some glass ionomer cements are intermediate. This most clearly simulates a real situation and will allow you to choose the necessary cement for fixing fixed structures of dentures.

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The Authors declare no conflict of interest.

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