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Research paper

Comparative Evaluation of Physical and Mechanical Characteristics of Composite facing Materials "Ceramage" and "Ultraglass"

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Abstract

In the oral cavity, mechanical loading and exposure to temperature leads to deformation of the frameworks of fixed prostheses and lining materials ensuring the proper level of their aesthetics. The increase of the isotropy of the material of the framework of a fixed prosthesis and the material that is facing it is one of the urgent problems in the field of orthopedic dentistry. In this paper, the linear thermal expansion coefficients (LTEC) of the facing materials “Ceramage Opaque Dentin”, “Ceramage Incisal”, produced by the Japanese company “Shofu”, and those of “UltraGlass” of the Russian firm “VladMiVa” were studied. The values of LTEC of facing materials were correlated with LTEC of cobalt-chromium alloy, used for making the frameworks of fixed prostheses. A comparative evaluation of the compressive strength, flexural strength, and modulus of elasticity of the specified composite materials used for facing the frameworks of fixed prostheses was also carried out.

Keywords: *linear thermal expansion coefficient, physical and mechanical characteristics, facing composite material, «ultra glass», «vladmiva».*

1.Introduction

At present, the demand for orthopedic treatment with fixed prostheses is increasing [1,2], taking place in the conditions of a consistently high level of aesthetic requirements of patients [3,4]. When choosing facing materials applied to the frameworks of fixed prostheses, their distinctive features and competitive advantages are assessed, including the economic benefits of the application, aesthetic qualities, physical and mechanical characteristics [5]. The last, in the indicated list, is the most significant, as the violation of the integrity of the prosthesis leads to its unconditional alteration. It should be taken into consideration that with the combined heating and loading of the prosthesis, the probability of a breach of its integrity increases [6].
One of the main reasons for the disruption of the integrity of orthopedic structures is the discrepancy between the LTEC of the framework and the lining material, as a result of which layers of the lining material with a thickness of more than 1.0 mm peel at critical temperatures [7].
In dental practice, cobalt-chromium alloys are considered optimal, in terms of "cost" and "biocompatibility" parameters, for the production of fixed prostheses. Depending on the equipment of the dental laboratory, their manufacture is possible using cast, milled or SLM-method [8].
The thermal expansion of solids is a consequence of the increase in the kinetic energy of atoms. The displacement of atoms relative to each other, summing up, leads to a change in the volume of the body. Thus, LTEC is an indicator characterizing the increase in the amplitude of thermal vibrations of atoms with an increase in body temperature by 10 K. Due to the anisotropy of the bodies the LTEC may be different in different direction [9,10]. The coefficient of volume expansion (β) of the crystal is approximately equal to the sum of its LTEC in three directions: $\beta = \alpha 1 + \alpha 2 + \alpha 3$. In the study of LTEC of polycrystalline samples, measurements are taken in one arbitrary direction [11].
When planning the combination of fixed prosthesis materials, the strength of the facing material, characterizing the resistance of the material to the occlusal loads, and the coefficient of the elastic modulus determining the stiffness of the material and its ability to withstand the applied loads without significant deformations are of fundamental importance.
Based on many years of experience in the development of facing composite materials, the company "Shofu Dental" sells in the market Ceramage composite material, containing about 73% of microscopic ceramic filler. Ceramage is presented in a kit containing syringes with an opaque layer of "Ceramage Opaque Dentin" (Ceramage OD) and a syringe for restoration of the cutting edge "Ceramage Incisal" (Ceramage I). It is the high level of popularity of Ceramage that led to the comparison of its physical and mechanical characteristics with those of the developed material "UltraGlass".

2.Purpose of the study

- a comparative assessment of the physical and mechanical characteristics of Ceramage OD, Ceramage I and UltraGlass facing composite materials.
Objectives of the study:
1. to correlate LTEC of facing composite materials with LTEC indices of cobalt-chromium alloy;

2. to evaluate the physical and mechanical characteristics: the flexural strength, the modulus of elasticity and the compressive strength of the facing composite materials.

3.Materials and methods.

The evaluation of LTEC was carried out in accordance with the recommendations of ISO 6872-95 on the L 75 Platinum Series Linseis unit supporting the temperature range from 22 to 2000 ° C, with the horizontal location of the measuring cell. The software of the device is represented by 2 modules: data collection and processing, preparing and conducting measurements, and also processing the results obtained.
To determine LTEC, 6 samples of each of the investigated composite materials were made using a mold having a cavity with dimensions of 50.0 * 5.0 mm and 6 samples of the cobalt-chromium alloy "Modelstar S" ("Scheftner", Germany).
Before the beginning of the dilatometric tests, the original length of the sample was measured with a micrometer to within ± 0.01 mm and values were entered into the database. Dilatometric tests were carried out at a heating rate (5.0 ± 1.0) 0 C / min, the calculation was carried out automatically at temperatures: 30.0, 40.0, 50.0, 60.0 ° C.
Determination of flexural strength and elastic modulus is performed in accordance with ISO 10477-92 on an Instron 2519-107 test machine. For evaluation, 6 samples of each of the investigated composite materials were made. During preparation, one of the metal plates was covered with a polyester film and a mold for preparing samples was placed on it. The mold was filled with the test material, the second polyester film was placed on top and the sample was squeezed using a clamp to remove excess material. After filling the mold, the samples were polymerized on a Preci NT Shuttle II. The hardened samples were dropped into a vessel with distilled water and placed in a thermostat with the temperature of 37.0 ° C. for 24 hours. The samples were then transferred to an Instron testing machine. Calculation of flexural strengths, modulus of elasticity and statistical analysis of data was carried out automatically by the Bluehill-3 program.
Determination of the compressive strength is performed in accordance with ISO 604: 2002 on an Instron 2519-107 test machine. To carry out the tests, 6 samples of each of the investigated composite materials were made. A detachable mold having a cavity of 10.0 * 5.0 mm was filled with a small excess of composite material, the plate form was mounted in a screw clamp and the samples were polymerized on a Preci NT Shuttle II. Then the plates were removed and the ends of the sample were ground to obtain the smooth surface at right angle to the longitudinal axis. The hardened samples were kept in distilled water at 37.00C for 24 hours before the test. Calculation of the strength of the material under compression σc, Mpa, was carried out in the Bluehill-3 program.

4.Results of the study

Dilatometric temperature variations of Ceramage ° OD, Ceramage I and UltraGlass in the temperature range from 30.0 to 60.0 ° C are presented in Table 1.

Table 1 - LTEC indices of composite facing materials (10 - 6 * C ° -1)

Temperature (°C)	Cobalt-chromium alloy	Ceramage OD	Ceramage I	UltraGlass
30.0	4,64±0,14	4.70±0,35	4.46±0,19	7.89±0.12*
40.0	5,22±0,08*	12.77±0,28*	11.55±0,26*	11.24±0.51*
50.0	6,04±0,15*	18.94±0,09*	15.79±0,47*	13.35±0.27*
60.0	6,60±0,06*	26.29±0,50*	20.71±0,21*	14.60±0.31*

*- the differences between LTEC of facing composite materials and KTLR of cobalt-chromium alloy are significant at p <0.05

At a temperature of 30 ° C for Ceramage ° I, LTEC is the smallest and corresponds to 4.46 ± 0.19, a somewhat higher LTEC value was obtained for Ceramage ° OD - 4.70 ± 0.35. These values correspond to the LTEC of cobalt-chromium alloy. The LTEC of the UltraGlass material exceeds the values obtained for the analogs by 72.9 and 67.8%, respectively, and is equal to 7.89 ± 0.12, which exceeds the LTEC of the metal framework by 70.0%
At a temperature of 40 ° C, the LTEC of the UltraGlass material is 11.24 ± 0.51, which is 115.3% higher than the LTEC of the framework. The Ceramage ° I values were 11.55 ± 0.26; Ceramage ° OD - 12.77 ± 0.28, which exceeds the LTEC of cobalt-chromium alloy by 121.3 and 144.64%, respectively.
Increasing the temperature to 50 ° C leads to an increase in the UltraGlass LTEC up to 13.35 ± 0.27. At this temperature, the UltraGlass LTEC exceeds the LTEC of the cobalt-chromium alloy by 121.0%. The value of LTEC in Ceramage ° I is equal to - 15.79 ± 0.47, that of Ceramage ° OD is - 18.94 ± 0.09. These values exceed the UltraGlass LTEC by 18.2 and 41.8%, and that of the cobalt-chromium alloy by 161.4 and 213.6%, respectively.
When reaching 60 ° C, the highest LTEC is characteristic of Ceramage ° OD, dilatometric exponents of which exceed the LTEC of the metal framework by 298.3%, amounting to 26.29 ± 0.50. At this temperature, the LTEC of the Ceramage material I is somewhat lower - 20.71 ± 0.21, but it is 213.8% higher than the LTEC of the cobalt-chromium alloy. LTEC of UltraGlass at a value of 14.60 ± 0.31 exceeds the LTEC of the framework by 121.2%.
A comparative assessment of the physical and mechanical characteristics of facing composite materials is presented in Table 2.

Table 2 - Indicators of physical and mechanical characteristics of composite facing materials

Indicators / Representatives	Flexural strength MPa*	The modulus of elasticity GPa*	Compressive strength MPa*
Ceramage°I	146.62±2.03	12.45±0.51	272.45±0.24
Ceramage°OD	139.54±2,13	10.62±0,34	326.14±3,76
UltraGlass	193.74±0,59	15.35±0,17	212.55±0,54

*- the differences in physical and mechanical characteristics of composite lining materials are valid at p <0.05

The flexural strength of UltraGlass is 193.74 ± 0.59 MPa, which exceeds the indicators of Ceramage ° OD (139.54 ± 2.13MPa) by 38.8% and those of Ceramage ° I (146.62 ± 2.03) by 32.1%.
The modulus of elasticity of the UltraGlass material was 15.35 ± 0.17 GPa, that is 44.5% higher than the indicators of it in Ceramage ° OD (10.62 ± 0.34 GPa) and 23.3% higher than those of the Ceramage ° I (12.45 ± 0.51 GPa).
The compressive strength of the UltraGlass material was 212.55 ± 0.54 MPa, which is 53.4% less than that of Ceramage ° OD (326.14 ± 3.76 MPa) and 28.2% less than indicators of Ceramage ° I (272.45 ± 0.24 MPa).

5.Discussion

Adhesive retention of the lining material on the surface of the frame necessitates the exact reproduction of the thermal behavior of the framework by the lining material. With an increase of more than 1.0 mm in the thickness of the layer of the lining composite material, a stress difference arises, going up according to the increase of the thickness of the layer. If the LTEC of the framework material is significantly lower than the LTEC of the facing composite material, then tangential tension of stretch is produced when the temperature is affected. Radial microcracks appear in the array of the lining material, forming delayed cracks directed towards the surface. If, however, the LTEC of the alloy is much higher than the LTEC of the lining material, then the tangential compressive stress leads to the appearance of microcracks, almost parallel to the framework, which leads to chipping.

Thus, the correspondence of the LTEC of the facing material to the LTEC of the cobalt-chromium alloy determines the preference for selecting the composite material in the process of restoring the dentition with fixed prostheses.

To minimize the negative role of the anisotropy of LTEC, work is being intensified on the creation of production technologies for nanostructure composite materials that allow combining materials with different LTECs.

In this direction, two main trends were formed. The first is illustrated by the Ceramage material, which is distinguished by the presence of ceramic nanofillers in its composition.

The second representative is the UltraGlass material with reinforced nanofiber organic matrix. Thanks to the bimodal filler and the original oligomer formula, which is 79% full, UltraGlass combines the aesthetics of nanocomposite and abrasion resistance and the coefficient of thermal expansion corresponding to microhybrid materials. The occlusal load is conventionally divided into "compressive - vertical" and "non-axis - horizontal" components. In the process of destruction of the food clot, the compressive loads act only at the moment of central occlusion, at other times the complex fissure-tubercle interaction results in non-axial loads.

The compressive load, coaxial to the axis of the tooth, is evenly distributed, not concentrating at the junction of the lining material with the frame of the fixed prosthesis. The non-axial component leads to the appearance of tension-deforming states leading to a disruption in the integrity of the bridge prosthesis.

The above reasoning proves the significance of the indicator "modulus of elasticity" - a measure of the rigidity of the material. At a high value of this module, the material is rigid and unyielding. The material with a low value of the modulus of elasticity is flexible, that leads to a reduction in strength of the structure, due to the occurrence of fractures as a result of fatigue of the material.

The compressive strength indicator of UltraGlass is lower than that of Ceramage Opaque Dentin and Ceramage Incisal. At the same time, the ultimate strength for bending of UltraGlass exceeds that of the materials being compared, which, taking into account the longer time of action of non-axial occlusal loads and LTEC, allows UltraGlass to be recommended for wide clinical application.

6.Conclusion

1. LTEC of composite materials is largely determined by the reinforcement of nanofiber organic matrix and modified mineral filler.
2. At a temperature of 30, 40, 50, 60 ° C, the UltraGlass LTEC differs from the LTEC of the cobalt-chromium alloy by 70.0, 115.3, 121.0 and 121.2%, respectively; this range of the LTEC indicator is significantly narrower than the LTEC of Ceramage materials, which determines the preference for the choice of the lining material in the process of restoring the masticatory efficiency to fixed prostheses.
3. Composite material UltraGlass demonstrated the following parameters: compressive strength (212.55 ± 0.54), flexural strength (193.74 ± 0.59 MPa) and elastic modulus (15.35 ± 0.17), comparable to those of the imported Ceramage analogue.

References

[1] .Kopytov, A.A.,2014. Tekhnologizatsiya upravleniya informatsionno- kommunikativnym prostranstvom rossiyskogo vuza kak faktor povysheniya urovnya konkurentosposobnost. Dissertatsiya na soiskaniye uchenoy stepeni kandidata sotsiologicheskikh nauk [Technological management of the information and communication space of the Russian higher educational institution as a factor of increasing the level of competitiveness // Thesis for a candidate's degree in sociology] / A.A. Kopytov // Rossiyskaya akademiya narodnogo khozyaystva i gosudarstvennoy sluzhby pri Prezidente RF [Russian Academy of National Economy and Public Administration under the President of the Russian Federation], Oryol [In Russian]

[2] Makurdumyan, D.A., Yaltonsky, V.M., Kabanov, V.Yu., Maly, 2016. A.Yu. Vliyanie priverzhennosti pacientov rekomendaciyam stomatologov na rezul'taty reabilitacii pri chastichnom otsutstvii zubov [The impact of adherence of patients to the recommendations of dentists on the results of rehabilitation with partial absence of teeth] . Byulleten' Vserossijskogo obshchestva specialistov mediko-social'noj ehkspertizy, Reabilitacionno-reabilitacionnoj otrasli,4 : 62-67[Bulletin of the All-Russian Society of Specialists in Medico-Social Expertise, Rehabilitation and Rehabilitation Industry,4 : 62-67] [In Russian]

[3] Yatani, H.,2015. Esthetic prosthodontic treatment – The state-of-the-art / H. Yatani. Journal of Prosthodontic Research, 4 (59) : 216–219

[4] Korotkaya, A.R., 2017. Osobennosti ortopedicheskogo protezirovaniya metallokeramicheskimi konstrukciyami [Features of orthopedic prosthetics with metal-ceramic structures]. Nauchnyj obzor. Medicinskih nauk, 3 : 35-38 [Scientific review. Medical sciences, 2017, 3 : 35-38] [In Russian]

[5] Dimer, A.R., Arossi, G.A., Santos, L.H., Kappaun, D.R. ,2015. Effect of different post-cure polymerization treatment on composite resin hardness,. Revista Gaúcha de Odontologia, 63 : 426 – 431.

[6] Nasrin, S., Katsube, N., Seghi, R.R., Rokhlin, S.I., 2016. D statistical failure analysis of monolithic dental ceramic crowns. Journal of Biomechanics, 10 (49) : 2038–2046

[7] SebastianiM., MassimiF., MerlatiG., Bemporad, E., 2015. Residual micro-stress distributions in heat-pressed ceramic on zirconia and porcelain-fused to metal systems: Analysis by FIB–DIC ring-core method and correlation with fracture toughness. Dental Materials, 11 (31) : 1396–1405

[8] Li, J., Chen, C., Liao, J., Liu, L., Ye, X., Lin, S., Ye, J., 2017. Bond strengths of porcelain to cobalt-chromium alloys made by casting, milling, and selective laser melting . Journal of Prosthetic Dentistry, 1 (118) : 69-75.

[9] Lebedenko, I.Yu., Kitkina ,T.B., Dubova, L.V., Vavilova, T.P., 2014. Elementnyj sostav desnevoj zhidkosti pri pol'zovanii nes"emnymi zubnymi protezami iz splavov dragocennyh metallov v dolgosrochnoj perspective [Elemental composition of the gingival fluid when using non-removable dentures made of precious metal alloys in the long term] . Rossijskij stomatologicheskij zhurnal, 4: 16-20 [Russian dental journal, 2014, 4 : 16-20] [In Russian]

[10] Kopeikin, V.N., Dolbnev, I.B. Protezirovanie [Dental prosthetics] / V.N. Kopeikin, I.B. Dolbnev // Moscow: Medicine, 2000, 237 [Moscow: Medicine, 2000, 237] [In Russian]

[11] Afanasyev, V.K., Popova, M.V., Gladyshev, S.A., Herzen, V.V., Obukhov, G.V., Gorshenin, A.V. Invary [The Invars] / V.K. Afanasyev, M.V. Popova, S.A. Gladyshev, V.V. Herzen, G.V. Obukhov, A.V. Gorshenin // Novokuzneck 2006. 126 [Novokuznetsk, 2006. 126] [In Russian]