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CHARACTERISTICS OF THE PHYSICAL AND MECHANICAL PROPERTIES OF SELF-ETCHING SELF-ADHESIVE CEMENTS FOR INDIRECT RESTORATIONS IN A COMPARATIVE ASPECT

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The purpose of the study was to carry out a comparative analysis of self-etching self-adhesive double-fixation cements for indirect restorations in terms of physical and mechanical properties.

Materials and methods. For comparison, in terms of physical and mechanical parameters, a self-etching self-adhesive composite cement for indirect restorations “Maxcem Elite”, Kerr, California, USA was taken. “Maxcem Elite” refers to self-etching self-adhesive composite cements of double fixation, which has a number of positive qualities, such as high physical and mechanical properties, good aesthetic properties, radiopacity. We analyzed the following physical and mechanical parameters: the appearance of the paste, depth of hardening, mm, diametric strength, MPa, conical yield point according to Heppler, MPa, hardness according to Heppler, MPa, water absorption in 7 days, μg/mm^3, water solubility in 7 days μg/mm^3, adhesive strength, MPa, peel strength, MPa.

Results and discussion. According to the average test depth of hardening (mm) material “Maxcem Elite” is inferior to others: material Bifix QV by 14.9% and Relyx U 100 by 13.3%. This does not significantly affect the quality of the connection of the adhesive structure with the hard tissues of the tooth, especially due to the method we have developed for the preparation of abutment teeth in the manufacturing of adhesive pads.

On the other hand, according to the average value of the index of diametrical strength (MPa), the studied material “Maxcem Elite” is by 17.2% better than Bifix QV, and by 17.3% better than Relyx U 100.

Comparing these and other physical and mechanical properties of materials on average, one must bear in mind the random nature of these values. From the results of the study, it can be seen that the difference between the indicators of the Maxcem Elite material and analogues is confirmed at a very high level of significance.

The study of the level of water absorption indicates the probable absence of variability of the indicator of the studied material in comparison with comparable analogs. The value of the water solubility index of all the composites under study practically does not differ from the value of “Maxcem Elite” (within (2.5±0.1) %), and corresponds to the requirements of ISO 4046.

Conclusion. The research results show that the investigated composite material “Maxcem Elite” in the main parameters corresponds to analogs, in most of the indicators it combines their best characteristics. In it, the adhesive strength of the connection with the hard tissues of the tooth is noticeably enhanced and better peel strength makes it possible to profitably use this material “Maxcem Elite” for fixing the adhesive structures.

Keywords: bridge, self-etching self-adhesive cements, double-fixation cements, X-ray contrast, adhesive strength, peel strength.

Connection of the study with planned research works. This study is a fragment of the research work of the Department of Orthopedic Dentistry of the Bukovinian State Medical University “A multidisciplinary approach to the diagnosis, treatment and prevention of major dental diseases while maintaining the regenerative properties of tissues and restoring the prosthetic properties of anatomical structures in residents of Northern Bukovina” (state registration number 0116 U 002929) and “Etiopathogenetic aspects of the rehabilitation of the main dental diseases of the maxillofacial region” (state registration number 0121U109997).

Introduction. Recently, thanks to the rapid development of materials science and innovative technologies in dentistry, adhesive bridges have been widely used to restore the integrity of the dentition with small included defects, combining exceptional aesthetics, sufficiently high wear resistance, a gentle approach to abutment teeth, production speed and, according to the direct method, independence from the dental laboratory [1, 2, 3, 4]. Modern methods for

the manufacturing of these prostheses are provided for the preparation of abutment teeth, which is significantly different in volume from that in the case of traditional bridges and restoration of a missing tooth using photocomposite materials reinforced with fiberglass elements, which are enclosed in prepared cavities in abutment teeth adjacent to the defect [5]. However, as practical application shows, in functional terms, these constructions are slightly inferior to traditional bridges [6]. The reason for this is the insufficient area of the fixing elements or their irrational arrangement [7, 8].

One of the conditions for the long-term operation of these structures is their high strength and resistance to wear. To ensure such characteristics, it is necessary to plan the design of prostheses and rationally calculate the distribution of loads [8, 9, 10, 11]. Despite a series of studies in this direction, there are many unresolved issues regarding the formation of cavities in abutment teeth and fixation of the construction of adhesive bridges [12]. These disadvantages can certainly be eliminated by introducing and improving new designs of fixed prostheses, as well as by using new materials for their fixation [13, 14].

The purpose of the study was to carry out a comparative analysis of self-etching self-adhesive double-fixation cements for indirect restorations in terms of physical and mechanical properties.

Materials and methods. For comparison, in terms of physical and mechanical parameters, a self-etching self-adhesive composite cement for indirect restorations “Maxcem Elite”, Kerr, California, USA was taken. “Maxcem Elite” refers to self-etching self-adhesive composite cements of double fixation, which has a number of positive qualities, such as high physical and mechanical properties, good aesthetic properties, radiopacity [15, 16].

To comprehensively check the positive characteristics of the self-etching self-adhesive composite cement for indirect restorations “Maxcem Elite”, Kerr, California, USA, we examined its analogs “Bifix QV”, VOCO, Cuxhaven, Germany, “Relyx U 100”, 3M ESPE, Minnesota, USA. We analyzed the following physical and mechanical parameters: the appearance of the paste, depth of hardening, mm, diametric strength, MPa, conical yield point according to Heppler, MPa, hardness according to Heppler, MPa, water absorption in 7 days, μg/mm^3, water solubility in 7 days, μg/mm^3, adhesive strength, MPa, peel strength, MPa. The arithmetic mean of ten tests was taken as the test result with an accuracy of 0.1 MPa, if the difference between them did not exceed 5%. Measurements of property values were carried out on 75 samples (25 samples from each material) using the methods provided for by the international standards ISO 4049-2009, DSTU 31578-2012 and DSTU 31574-2012. The analysis and processing of the statistical data of the conducted studies was carried out on a personal computer using the application package Microsoft Office 2013.

Results and discussion. As shown by the results of the study (**Table 1**), all materials during the tests showed themselves as highly viscous, homogeneous pastes, in which there are no foreign impurities and inclusions. If the average value of a certain indicator for material with number k is equal to P_k, then the index I_k relative to the best average value is defined as (1.1) depending on whether the quality of the material directly depends on this indicator, or it falls with an increase in the indicator.

$$I_k = P_k / \max P_i \quad \text{or} \quad I_k = \min P_i / P_k. \qquad (1.1)$$

So, we see that according to the average test depth of hardening (mm) material “Maxcem Elite” is inferior to others: material Bifix QV by 14.9% and Relyx U 100 by 13.3%. This does not significantly affect the quality of the connection of the adhesive structure

Table 1 – Summary table of the main physical and mechanical parameters of the light-curing materials “Maxcem Elite ™” and its analogs

Indicator and its designations, units of measurement, clarification	Average and standard deviation for material		
	“Maxcem Elite ™”, Kerr, California, USA	**“Bifix QV”, VOCO, Cuxhaven, Germany**	**“Relyx U 100”, 3M ESPE, Minnesota, USA**
The appearance of the paste is highly	Viscous, homogeneous	Viscous, homogeneous	Viscous, homogeneous
Depth of hardening, mm, not less (H)	4.62±0.25*	5.4±0.27	5.3±0.26
Diametral strength, MPa (D)	47.34±2.64*	44.1±2.2	44.0±2.2
Heppler conical yield point, MPa, not less (C)	1514.72±80.3*	1476.5±73.8	1489.3±74.5
Heppler hardness, MPa, not less (S)	784.66±42.3	732.6±36.6	756±37.8
Water absorption in 7 days, μg/mm^3, not more (W)	7.34±0.32	7.6±0.38	7.2±0.36
Water solubility in 7 days, μg/mm^3, not more (U)	4.23±0.17*	3.2±0.16	3.1±0.16
Adhesive strength, MPa, not less (A)	17.31±0.54*	7.1±0.36	7.92±0.4
Peel strength, MPa, not less (R)	5.32±0.27*	4.6±0.23	5.0±0.25

***Note:* * –** significant difference ($p < 0.05$) “Maxcem Elite ™” in comparison with the best analog.

with the hard tissues of the tooth, especially due to the method we have developed for the preparation of abutment teeth in the manufacture of adhesive pads. On the other hand, according to the average value of the index of diametrical strength (MPa), the studied material "Maxcem Elite" is by 17.2% better than Bifix QV, and by 17.3% better than Relyx U 100 [12].

Comparing these and other physical and mechanical properties of materials on average, one must bear in mind the random nature of these values. From (**Table 2**) it can be seen that the difference between the indicators of the material "Maxcem Elite" and analogs is confirmed at a very high level of significance.

Therefore, the level of reliability of these comparisons can only be asserted by conducting an appropriate statistical analysis. None of the samples that were analyzed was a sample with a normally distributed general population (according to the Kolmogorov-Smirnov test), therefore, in our calculations, we used the methods of nonparametric statistics.

Table 2 – Results of statistical analysis of comparisons of physical and mechanical properties of the material "Maxcem Elite ™" and its analogs by the Mann-Whitney test

Indicators	Significance level p
$H_{Maxcem\ Elite}$ and H_{Relyx} (versus smallest value)	2.6×10^{-6}
$D_{Maxcem\ Elite}$ and D_{Bifix} (compared to the best value)	7.0×10^{-8}
$C_{Maxcem\ Elite}$ and C_{Relyx} (compared to the best value)	0.0011
$S_{Maxcem\ Elite}$ and S_{Relyx} (compared to the best value)	9.2×10^{-5}
$A_{Maxcem\ Elite}$ and A_{Relyx} (compared to the best value)	1.110^{-13}
$C_{Maxcem\ Elite}$ and C_{Relyx} (compared to the best value)	0.0011
$R_{Maxcem\ Elite}$ та R_{Relyx} (compared to the best value)	0.013

The results obtained relate to all comparisons of the material "Maxcem Elite" according to the indicators included in **Table 2**. For example, we came to the conclusion (**Table 1**) about a high reliable advantage in terms of Heppler conical yield point over the best of comparable materials Relyx U 100 (C = 1489.3±74.5 MPa). Since it is the best, the preference of the material "Maxcem Elite" over others can be asserted in no way at a lower level of reliability. Comparing the indicators of water absorption, water solubility and peel strength, the situation was the opposite [11].

The study of the level of water absorption indicates the probable absence of variability of the indicator of the studied material in comparison with comparable analogs. The value of the water solubility index of all the composites under study practically does not differ from the value of "Maxcem Elite" (within (2.5±0.1) %), and corresponds to the requirements of ISO 4046. These conclusions are also confirmed statistically, since none of the applied criteria were indicated for the presence of significant differences. Note that the last two indicators affect the stability of the glue line and the toxic effect on the human body [13].

Among the most important strength characteristics for fixing materials are the adhesive strength of the connection with the hard tissues of the tooth and the peel strength. In terms of adhesive strength of bonding to hard tissues, the undisputed leader was "Maxcem Elite", which, by comparison of average measurement values, surpasses Bifix QV by 37.2%, and Relyx U 100 by 30%, and, according to **Table 2** benefit significance is very high ($p < 0.001$). Relative to the peel strength index, which was approximately the same for "Maxcem Elite" (5.32±0.27) MPa and Relyx U 100 (5.0±0.25) MPa and better by 13.6% with respect to Bifix. But, as can be seen from the **Table 2**, the advantage of "Maxcem Elite" in relation to Relyx U 100 can be asserted at a satisfactory level of significance $p < 0.01$ [11].

The high level of adhesive strength of the connection with hard tissues of the tooth and the peel strength ensures the reliability and durability of the connection of the enamel-composite-metal system.

Thus, on the basis of laboratory tests and statistical analysis of their results, we substantiated the following conclusion.

Conclusion. The research results show that the investigated composite material "Maxcem Elite" in the main parameters corresponds to analogs, in most of the indicators it combines their best characteristics. In it, the adhesive strength of the connection with the hard tissues of the tooth is noticeably enhanced and better peel strength makes it possible to profitably use this material "Maxcem Elite" for fixing the adhesive structures.

Thus, based on the results of a comprehensive comparative characteristic of the physical and mechanical properties of the composite materials under study, it can be concluded that this material can be offered for clinical use, namely, for fixing bridges, is the method of choice in the treatment of small included defects in the dentition in the frontal area. Film thickness index (μm) according to laboratory tests of Relyx U100 and Bifix QV has a value lower than the standards recommended by ISO. "Maxcem Elite" corresponds to the minimum limit of indicators, which is (25.7±2.9) microns.

The advantage of this type of polymerization is its reliability and it allows the physician to thoroughly remove the excess fixative material already at the gel stage before the final photopolymerization. Its second advantage is that there is no adhesive in the composition, which reduces the likelihood of toxic manifestations from the pulp and periodontal tissues. Full color

matching of “Maxcem Elite” material according to the Vita scale allows for prosthetics of bridges in the anterior part of the dentition without violating the norms of aesthetics.

Thus, “Maxcem Elite” is a material that combines high viscosity of the polymer matrix, low dispersion of the filler, which provides it with high plasticity. This allows a thin layer of material to be obtained between the adhesive pad and the hard tissues of the tooth. High bond strength with hard tooth tissues, which is 1.6 times higher than the requirements, in combination with a high level of peel strength, which is 1.52 times higher than the requirements, allows you to obtain a reliable fixation with a metal surface, which is a prerequisite for using this type of prosthetics. The high value of the hardening depth (4.6 mm) expands the possibilities of using bridges with metal frameworks due to the full polymerization due to double fixation and mechanical retention.

Perspectives of further research. We are planning to substantiate the expediency of choosing a fixing material depending on the method of preparation of abutment teeth, structural materials of bridges with adhesive fixation, which will help the dentist to improve clinical efficiency and avoid possible complications.

References

1. Dvornikova TS. Volokonnoe armirovanie v povsednevnoj klinicheskoj praktike. Chast II. Sozdanie adgezivnyh mostovidnyh protezov [Fiber reinforcement in everyday clinical practice. Part II. Creation of adhesive bridges]. *Institut stomatologii*. 2009;4:38–41. [Russian]
2. Kaveckij VP. *Kliniko-laboratornoe obosnovanie primeneniya adgezivnyh volokonnyh konstrukcij v esteticheskoj stomatologii* [Clinical and laboratory substantiation of the use of adhesive fiber structures in aesthetic dentistry]. Abstr. PhDr. (Med.). Minsk; 2013. 22 s. [Russian]
3. Kaveckij VP, Polyakov KM. *Adgezivnye mostovidnye protezy: uchebno-metodicheskoe posobie* [Adhesive bridges: teaching aid]. Minsk: BelMAPO; 2009. 14 p. [Russian]
4. Grigoreva EA, Bolonkin VP, Belousova LG, Hajkin MB, Shevchuk EN. Obosnovanie primeneniya novogo adgezivnogo mostovidnogo proteza pri vosstanovlenii malyh defektov zubnyh ryadov [Rationale for the use of a new adhesive bridge prosthesis in the restoration of small defects in the dentition]. *Izvestiya Samarskogo nauchnogo centra RAN*. 2015;17(1–3):770–3. [Russian]
5. Parhamovich SN, Tyukova EA. Sovremennye podhody primeneniya volokonnyh armiruyushih sistem dlya adgezivnogo shinirovaniya i mikroprotezirovaniya [Modern approaches to the use of fiber reinforcement systems for adhesive splinting and microprosthetics]. *Sovremennaya stomatologiya.* 2016;3:43–8. [Russian]
6. Kazeko LA, Boriseeva, OA, Baranovskaya MS. *Volokonnye sistemy v terapevticheskoj stomatologii: uchebno-metodicheskoe posobie* [Fiber systems in therapeutic dentistry: a teaching aid]. Minsk: BGMU; 2010. 24 p. [Russian]
7. Nikolaev YuM. Novoe pokolenie fiksiruyushih cementov v klinike ortopedicheskoj stomatologii [A new generation of luting cements in the clinic of orthopedic dentistry]. *Problemy stomatologii*. 2012;3:50-3. [Russian]
8. Mironov EA. Obosnovanie vybora fiksiruyushego agenta dlya nepryamyh restavracij [Rationale for the choice of luting agent for indirect restorations]. *Bulletin of Medical Internet Conferences*. 2014;4(5):756-9. [Russian]
9. Daiichiro Y, Akikazu Sh, Harunori G, Pekka KV, Akiyoshi Sh. Effects of Mechanical Properties of Adhesive Resin Cements on Stress Distribution in Fiber-Reinforced Composite Adhesive Fixed Partial Dentures. *Dent Mater J.* 2012;31(2):189-196. PMID: 22447051. doi: 10.4012/dmj.2011-104
10. Maxcem Elite™ Samoprotravlivayushij, samoadgezivnyj kompozitnyj cement dlya postoyannoj fiksacii [Maxcem Elite™ Self-etching, self-adhesive composite cement for permanent luting]. [Russian]. Available from: https://www.kerrdental.com/ru-ru/
11. Yanishen IV, German SA, Yarina IM, Sidorova OV, Sorohan MM. Porivnyalna ocinka fiziko-mehanichnih vlastivostej stomatologichnih cementiv dlya postijnoyi fiksaciyi ortopedichnih konstrukcij [Comparative Evaluation of Mechanical and Physical Properties of Dental Cements for Permanent Fixation of Orthopedic Dentures]. *Ukrayinskij zhurnal medicini, biologiyi ta sportu*. 2018;6(15):240-4. [Ukrainian]. doi: 10.26693/jmbs03.06.240
12. Sorohan MM, Byelikov OB, Byelikova NI, Byelikova LO. Analiz fiziko-mehanichnih vlastivostej kompozitnogo materialu Maxcem Elite™ u porivnyalnomu aspekti z fiksuyuchimi materialami dlya nepryamih restavracij [Analysis of physical and mechanical properties of composite material by Maxcem Elite™ in comparative aspect with fixing materials for indirect restorations]. Eurasian scientific congress. Abstracts of the 7th International scientific and practical conference. Barca Academy Publishing. Barcelona, Spain; 2020. 2020. p. 94-98. [Ukrainian]. Available from: https://sci-conf.com.ua.
13. Kuznecov RV. *Planuvannya opornih elementiv ta udoskonalennya metodiv fiksaciyi adgezivnih mostopodibnih proteziv* [Planning of support elements and improvement of methods of fixing adhesive bridges]. Abstr. PhDr. (Med.). Poltava; 2006. 168 p. [Ukrainian]
14. Ferracane JL, Stansbury JW, Burke FJ Self-adhesive resin cements - chemistry, properties and clinical considerations. *J Oral Rehabil*. 2011;38(4):295-314. PMID: 21133983. doi: 10.1111/j.1365-2842.2010.02148.x

15. Makkenzi BL. Fiksatsiya nepryamoy restavratsii na tsement Maxcem Elite Chroma [Cementation of an indirect restoration with Maxcem Elite Chroma cement]. Dental Tribune. 2017 May 09. Available from: https://ru.dental-tribune.com/clinical/ [Russian]
16. Muradov MA. Samoadgezivni kompozytni tsementy v praktytsi ortopedychnoyi stomatologiyi [Self-adhesive composite cement in the practice of orthopedic dentistry]. *Klinichna stomatologiya*. 2013;4:30–7. [Ukrainian]

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ХАРАКТЕРИСТИКА ФІЗИКО-МЕХАНІЧНИХ ВЛАСТИВОСТЕЙ САМОПРОТРАВЛЮЮЧИХ САМОАДГЕЗИВНИХ ЦЕМЕНТІВ ДЛЯ НЕПРЯМИХ РЕСТАВРАЦІЙ У ПОРІВНЯЛЬНОМУ АСПЕКТІ

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Резюме. *Метою* дослідження було проведення порівняльного аналізу самопротравлюючих, самоадгезивних цементів подвійної фіксації для непрямих реставрацій за фізико-механічними властивостями.

Матеріал та методи. Для порівняння за фізико-механічними показниками був взятий самопротравлюючий самоадгезивний композитний цемент для непрямих реставрацій «Maxcem Elite», Kerr, California, USA. Були досліджені аналоги «Maxcem Elite» - Bifix QV, VOCO, Cuxhaven, Germany, Relyx U 100., 3M ESPE, 3M ESPE, Minnesota, USA. Проаналізовано фізико-механічні показники: зовнішній вигляд пасти, глибина затвердіння (мм), діаметральна міцність (МПа), конічна межа плинності по Хепплеру (МПа), твердість по Хепплеру, МПа, водопоглинання за 7 діб (мкг/мм 3), розчин у воді через 7 діб (мкг/мм3), адгезійна міцність (МПа), міцність на відрив (МПа).

Результати. За середньою глибиною затвердіння (мм) матеріал «Maxcem Elite» поступається іншим матеріалам Bifix QV на 14,9% і Relyx U 100 на 13,3%. Але це не впливає на якість з'єднання адгезивної конструкції з твердими тканинами зуба. За середнім значенням показника діаметральної міцності (МПа) досліджуваний матеріал «Maxcem Elite» на 17,2 % краще, ніж Bifix QV, і на 17,3 % краще, ніж Relyx U 100. Різниця між показниками матеріалу Maxcem Elite та аналогів підтверджується на дуже високому рівні значущості. При порівнянні показників водопоглинання, водорозчинності та міцності на відрив ситуація була протилежною. За адгезійною міцністю зчеплення з твердими тканинами беззаперечним лідером став «Maxcem Elite», який при порівнянні середніх показників вимірювань перевищує Bifix QV на 37,2 %, а Relyx U 100 на 30 %, причому значущість переваги рівня 2 дуже висока (P <0,0). Показник міцності на відрив був приблизно однаковим для «Maxem Elite» (5,32±0,27) МПа та Relyx U 100 (5,0±0,25) МПа, і краще на 13,6% по відношенню до Bifix QV.

Висновки. Композиційний матеріал «Maxcem Elite» за основними параметрами відповідає аналогам, по більшості показників поєднує їх кращі характеристики. У ньому помітно підвищена адгезійна міцність з'єднання із твердими тканинами зуба, а найкраща міцність на відрив дозволяє вигідно використати цей матеріал «Maxem Elite» для фіксації адгезивних конструкцій.

Ключові слова: мостоподібний протез, самопротравлюючі самоадгезивні цементи, цементи подвійної фіксації, рентгеноконтрастність, адгезійна міцність, міцність на відрив.

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