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Comparative characteristics of the physical and mechanical properties of the self-etchable self-adhesive composite cement for indirect restorations "Maxcem Elite™"

ІНФОРМАЦІЯ

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АНОТАЦІЯ

Summary. The article deals with an actual problem of orthopedic dentistry: the choice of a reliable material for fixing indirect restorations by comparing the physical and mechanical properties of self-adhesive self-etching composite cements.

The aim of the study – 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, $\mu\text{g}/\text{mm}^3$, water solubility in 7 days $\mu\text{g}/\text{mm}^3$, 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 $(2.5 \pm 0.1) \%$), and corresponds to the requirements of ISO 4046.

Conclusions. 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.

Introduction. One of the most important problems in the use of adhesive fixation bridges, which reduces the level of their widespread use, is the lack of high-quality and affordable fixation material [2, 5].

Therefore, using the modern achievements of chemical science and the requirements for clinical application, it can be considered relevant to select the components of the material and their rational ratio, which would combine the low viscosity of the polymer matrix and the high dispersion of the hybrid filler, which makes it possible to achieve high plasticity and prevent the formation of a thick layer of material between the adhesive pad and the tooth surface [1, 3].

Objective. To analyze in a comparative aspect the physical and mechanical properties of the polymer material "Maxcem Elite™" as a fixing material for bridges of the adhesive fixation system.

Material and methods. The composite material "Maxcem Elite™" is made on the basis of a monomeric matrix consisting of organic components: Bis-GMA, urethane dimethacrylate triethylene glycol dimethacrylate – 18.8 % by weight, inorganic fillers – 81.0 % by weight, a small amount of catalysts, stabilizers and pigments – 0.2 % by weight. The amount of inorganic fillers is 81 % by weight and 68 % by volume. Particle size 0.04–7.0 microns [4, 6].

The study of the physical and mechanical properties of the material "Maxcem Elite™" was carried out according to the following indicators: the appearance of the paste and adhesive, their consistency; the appearance of the polymer; diametrical strength; water absorption and water solubility; strength and conical yield point according to Heppler; tensile strength; adhesive strength of connection with hard tissues of the tooth, etc.

Results and discussion. On the basis of the laboratory studies it was found that absolutely all characteristics of "Maxcem Elite™" comply with the requirements of ISO 4046-81 and TU.U.24.4-00481318-022-2002 [6]. Improved cement formula provides adhesion strength comparable to total-etch adhesives to tooth tissues and all types of dental materials without the use of an adhesive system (MPa enamel – 25.5, dentin – 25.8, titanium – 41, zirconium – 32.1 gold – 33.2, E. max – 34, ceramics – 33.6). An optimized matrix and filler system enhances lubricity, resulting in better adhesion to dentin [4].

In terms of the main quality indicators, such as high bond strength to hard tooth tissues, which is

1.6 times higher than the requirements in combination with a high level of peel strength and 1.5 times higher than the requirements, it allows you to obtain reliable fixation, which is a prerequisite when using this type of prosthetics. The high value of the hardening depth (4.6 mm) is 2.3 times higher than the standards, thereby expanding the possibilities of using adhesive bridges with metal frames. Our comparative analysis of the physical and mechanical properties of the investigated material "Maxcem Elite™" with analogues (Bifix VOCO, Relyx U 100 3M ESPE), allowed us to reveal the following regularities (table 1).

All investigated materials during the tests showed themselves as high-viscosity, homogeneous pastes in which there are no foreign impurities and inclusions. Although in terms of the depth of hardening "Maxcem Elite™" is reliably ($p < 0.05$) inferior, Bifix is by 14.9 % and by 13.3 % Relyx U 100, this does not significantly affect the quality of the bond of the adhesive structure with hard tooth tissues, especially due to the developed by us method of preparation of abutment teeth for adhesive onlays of bridges.

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 corresponded to the sample from the normally distributed general population (according to the Kolmogorov-Smirnov test), therefore, in our calculations, we used the methods of nonparametric statistics (table 2).

The results obtained relate to all comparisons of the material "Maxcem Elite™" in terms of the indicators included in table 2. For example, we came to the conclusion (see table 1) about a high reliable advantage in terms of Heppler's conical yield point over the best of comparable materials Relyx U 100 ($C = 1489.3 \pm 74.5$ 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. By comparing the indicators of water absorption, water solubility and peel strength, the situation was the opposite.

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 studied composites practically does not differ from the value of "Maxcem Elite™" (within $(2.5 \pm 0.1)\%$), and comply with the requirements of ISO 4046. These conclusions are also confirmed statistically, since

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 analogue.

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

Indicators	Significance level p
H _{Maxcem Elite} та H _{Relyx} (versus smallest value)	2.6·10 ⁻⁶
D _{Maxcem Elite} та D _{Bifix} (compared to the best value)	7.0·10 ⁻⁸
C _{Maxcem Elite} та C _{Relyx} (compared to the best value)	0.0011
S _{Maxcem Elite} та S _{Relyx} (compared to the best value)	9.2·10 ⁻⁵
A _{Maxcem Elite} та A _{Relyx} (compared to the best value)	1.110 ⁻¹³
C _{Maxcem Elite} та C _{Relyx} (compared to the best value)	0.0011
R _{Maxcem Elite} та R _{Relyx} (compared to the best value)	0.013

none of the applied criteria 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.

Analyzing the indicators of the diametral strength of the materials under study, we can reliably (p<0.001) note the indicators of "Maxcem Elite™" higher than Bifix by 17.2 %, and higher than Relyx U 100 by 17.3 %. Also, other physical and mechanical properties of the material "Maxcem Elite™" have a significant (p<0.0015) advantage. So, in terms of Heppler conical yield point between "Maxcem Elite™" (1673.7±0.68) MPa and Bifix (1476.7±0.75) MPa, the result of which is 8.6 % less and Relyx U 100 (1489.3±1.94) MPa – less by 7.8 %. The Heppler hardness "Maxcem Elite™" is practically at the level(p<0.05) of the Bifix and

Relyx U 100 indicators at (839.6±41.9) MPa and (732±36.6) MPa and (756±37.8) MPa, respectively. All this indicates the high mechanical strength of the material under study.

The study of the level of water absorption indicates a significant absence of variability of the indicator of the studied material in comparison with a comparable analogue. This indicator for "Maxcem Elite™" is significant and reliable (at the level of p>0.0001), less compared to Relyx U 100 (by 20 %). 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 comply with the requirements of ISO 4046. We believe that statistical analysis confirms this, since the difference between " Maxcem Elite™ "and Relyx

U 100 could be asserted only at an extremely low level of significance ($p > 0.18$).

Among the most important strength characteristics for luting materials are the adhesive strength of the bond to 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 significantly ($p < 0.001$) and significantly surpasses Bifix by 37.2 %, and Relyx U 100 by 30 %. 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 the best by 13.6 % in relation to Bifix. But, as shown by an accurate analysis (table 2), the advantage of "Maxcem Elite™" in relation to Relyx U 100 can be asserted at a high level of significance $P < 0.013$. The high level of adhesive strength of the connection with hard tooth tissues and peel strength ensures the reliability and durability of the enamel-composite-metal system connection, which makes it possible to use this material for fixing adhesive structures.

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 made the following conclusions.

Conclusions. In a comparative aspect, a study was made of the physicomachanical properties of composite cements for indirect restoration. It was found that in terms of adhesive strength of bonding with hard tissues,

Maxcem Elite™ turned out to be the undisputed leader, which by average measurements exceeds Bifix by 37.2 % and Relyx by 30 %, and the significance level of the advantage is very high ($P < 0.001$). The peel strength looked approximately the same for the "Maxcem Elite™" (5.32 ± 0.27) MPa and Relyx (5.0 ± 0.25) MPa and was 13.6 % better with respect to Bifix. Therefore, the advantage of "Maxcem Elite™" in relation to Relyx U 100 can be affirmed at a satisfactory significance level of $p < 0.01$. A high level of adhesion strength to tooth hard tissues and peel strength ensures reliability and durability of the enamel-composite-metal system.

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Порівняльна характеристика фізико-механічних властивостей самоадгезивного самопротравлювального композитного цементу для непрямих реставрацій «Maxcem Elite™»

Резюме. У статті розглянуто актуальну проблему ортопедичної стоматології, вибір надійного матеріалу для фіксації непрямих реставрацій шляхом порівняння фізико-механічних властивостей самоадгезивних самопротравлювальних композитних цементів.

Мета дослідження – провести порівняльний аналіз самоадгезивних самопротравлювальних цементів подвійної фіксації для непрямих реставрацій за фізико-механічними властивостями.

Матеріали і методи. Для порівняння за фізико-механічними показниками було взято самопротравлювальний самоадгезивний композитний цемент для непрямих реставрацій «Maxcem Elite», Kerr, California, USA. Було досліджено 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 за Хеплером (МПа), твердість за Хеплером, МПа, водопоглинання за 7 діб (мкг/мм³), розчин у воді через 7 діб (мкг/мм³), адгезійна міцність (МПа), міцність на відрив (МПа).

Результати досліджень та їх обговорення. 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 із 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 «Maxcem Elite» ($5,32 \pm 0,27$) МПа та Relyx U 100 ($5,0 \pm 0,25$) МПа і краще на 13,6 % відносно Bifix QV. **Висновки.** Композиційний матеріал «Maxcem Elite» за основними параметрами відповідає аналогам, за більшістю показників поєднує їх кращі характеристики. У ньому помітна підвищена адгезійна міцність з'єднання із твердими тканинами зуба, а найкраща міцність на відрив дозволяє вигідно використати матеріал «Maxcem Elite» для фіксації адгезивних конструкцій.

Ключові слова: мостоподібний протез; самоадгезивні самопротравлювальні цементи; цементи подвійної фіксації; адгезійна міцність; міцність на відрив.

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