Optimized Approach of Dental Composites Identification with The Use of Original Spectrophotometric Algorithm

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Abstract

The formation and development of the different dental markets and services, as well as numerous organizations with different forms of ownership, provoke the occurrence of quality control problem of various dental materials used in practice. Objective of research was to develop a method for the primary identification of changes in physical properties of photopolymer composite materials in comparison with features of reference samples, registered by the method of spectrophotometry. At the first stage of research official distributed composite syringes shades A1, A2 and A3 of different brands were collected. Prepared samples of investigated materials were placed inside spectrophotometer SF-2000, and indicators of absorption, transmission and reflection of light in the range of waves from 350 to 850 nm were recorded. At the second stage composite syringes of the same manufacturers and shades as in the first stage were collected, but without control of their official distribution. Subsequently, a comparison of the results of the study samples and reference database samples was performed in the adapted software. 96 experimental samples (83,48%) corresponded to the parameters previously registered in formed database of absorption, transmission and reflection in the range of 92,5-96,7% concordance (P<0.05), 10 study samples (8,69%) corresponded to the reference values of 61,8-65,2% concordance (P<0.05), 9 study samples (7,83%) corresponded to the reference values of 33,5-45,6% concordance (P <0.05). During analysis it was found that results of comparison transmission and reflective coefficients among reference and study samples were the closest at wavelength range of 550-600 nm and 800-850 nm. Proposed approach helps to prevent the use of composite materials with non-sufficient physical properties registered by spectrophotometric method, samples of which could be presented at the grey market and objectively non attributed to any manufacture’s brand.

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Introduction

Dental care service remains one of the most popular types of medical care, therefore ensuring its high quality is the priority task for the corresponding dental health facilities[1,2,3]. The formation and development of the different dental markets and services, as well as numerous organizations with different forms of ownership, provoke the occurrence of quality control problem of various dental materials used in practice[4,5,6]. Problem of dental quality control has also raised due to the emergence of more complaints from patients and corresponding lawsuits, registered in past decade. On the other hand, one of the fundamental idea of medical reforms in most countries of the world is to optimize the cost of medical care and progressively improve its quality[5,6]. The growth of the number of scientific publications devoted to the development of the methods and progressive experience in the field of quality control of medical care also indicates about the multicomponent character and complexity of this problem, which requires an integrated and systematic approach to its solution.

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A direct assessment of the various types of dental care quality is carried out in accordance with a set of pre-established criteria, some of which were recommended by the FDI and implemented in the relevant WHO cards, while others were accepted during consensus conferences for use in practice[7,8]. At the same time, the review of criteria for assessing the provision of basic dental services is constantly improving, based on changing approaches to the treatment and diagnostic capabilities in dental practice. For example, in a systematic review of Papaspyridakos et al., who provided the analysis of 25 studies, criteria for assessing the quality of implantation that were most often used in previous clinical trials were identified[9], but other authors noted that there was a problem not only to systematize the main criteria for assessing the quality of the procedure, but also to adequately register them with diagnostic methods that allow objectivize corresponding changes[10].

Given the increasing role of aesthetic criteria for dental rehabilitation, updated FDI criteria for the evaluation direct and indirect restorations by aesthetic, functional and biological parameters were published[7],[8]. However, a number of preliminary studies indicate that the success of dental restoration is based not only on compliance with the relevant principles of its implementation, doctor's experience and clinical conditions, but also on the quality of the material selected for each particular clinical situation. The increasing progress in the technology of producing photopolymer composites, possibility of achieving appropriate level of biomimetic, reasoned price and the opportunity for direct restoration of tooth defect within one or more dental procedures, substantiate the prevalence of photocomposites as the material of choice for direct restorations.

However, the growing demand for photopolymer materials and the impossibility of full control over the quality of products in the conditions of the spontaneous replated dental market by different firms and brands, provoked a situation where the distribution of some composite samples vend within the conditions of an uncontrolled subdealer. Christensen G. J. highlighted the existence of the gray market of stomatological materials, and the author identified the next main criteria for identifying unoriginal products: "a relatively lower price, an unidentified distributor's name, questionable product packaging, and an unknown date for the expiration of the shelf-life"[11]. However, such criteria allow us to verify potentially hazardous material at the time of disposals, and do not contribute to the assessment of the actual physical properties of a particular type of dental composite, which determine the effectiveness of its use in practice. Fundamental from this point of view is the work of Souder W. H. & Peters C. G., in which the authors firstly described approaches for the evaluation of specific physical parameters of dental materials[12]. The approach described by the authors is comprehensive and well-grounded, but difficult to use in practice. Its analogues are used during the examination of materials during their state registration in different countries, but the introduction of such tests for the conformity of a particular composite syringe quality is financially unreasonable and time-consuming.

Thus, there was a need to develop an algorithm to assess the conformity of dental materials, in particular, photopolymer composites, taking into account their prevalence at the market, and compare to their quality parameters that are typical for products sold by the official distributor.

The present research **aims** to develop a method for the primary identification of changes in physical properties of photopolymer composite materials in comparison with features of reference samples, registered by the method of spectrophotometry.

Materials and methods

The program for developing the method of primary identification of photopolymer composite material physical changes in comparison with the features of reference samples, registered by the spectrophotometry method, envisaged the implementation of two research stages.

At the first stages official distributed composite syringes shades A1, A2 and A3 of Filtek Z250 (3M) (microhybrid composite), Charisma (microhybrid composite), i-XCITE LCN (i-dental) (nanohybrid composite), Sagen balance (Crom Dental) (nanohybrid), Esterit Sigma Quick (Tokuyama Dental) (supranano composite), Spectrum TPH3 (DENTSPLY) (sub-micron hybrid composite) were collected. From each composite material, a disc was prepared with a diameter of 1 mm and a thickness of 1 mm, which was polymerized according to manufacturer's instructions (reference samples). After that prepared samples of investigated materials were placed inside spectrophotometer SF-2000 (LOMO, Russia), and indicators of absorption, transmission and reflection of light in the range of waves from 350 to 850 nm were recorded. For each sample study was repeated three times, thus registering the average of the obtained values. The resulting numerical values were entered in Microsoft Excel 2016 software (Microsoft Office, 2016), where they were initially systematized and prepared for further processing in the MedCalc software (MedCalc Software). After systematizing the indicators, a reference database was obtained, which later was used to compare the results obtained during the subsequent experiment.

At the second stage, research was carried out among private clinics in Uzhhorod city (Ukraine) and at the University Dental Clinic (Uzhhorod National University, Faculty of Dentistry), where we collected syringes from the same manufacturers and shades as in the first stage, but without control of their official distribution. The criteria for inclusion in the sample were as follows: the doctor's agreement on the providing the syringe of the material for the investigators, suitability of the syringe by the exposure date and the absence of any damages of the composite syringe. This way it was possible to form a sample of 115 sample objects. From each syringe selected for study we formed discs of 1 mm in diameter and 1 mm in thickness (study samples), which were polymerized according to the manufacturer’s instructions. Subsequently, a comparison of the results of the study samples and reference database samples was performed in the Microsoft Excel 2016 software (Microsoft Office, 2016).

Concordance correlation coefficients between reference samples and experimental samples were calculated due to the instructions provided by Lin (1989)[13,14]. In our research it helped to evaluate the agreement between absorption, transmission and reflection values of the referent and study samples with Pearson's p (precision) and bias correction factor Cb (accuracy). McBride's (2005) descriptive scale was used to interpret the obtained concordance correlation coefficient values[16]. To evaluate the relationship between the results obtained during the first and second phase of research, the difference between numerical data was regressed on the average values obtained with use of above mentioned statistical methods. Pearson's r was used to measure the possible linear correlation between variables of shade of composite and mean reflecting coefficient range, mean transmission coefficient range and mean absorption coefficient range, recorded by spectrophotometric method. Linear and quadratic regression analyzes were provided for modeling the relationship between a scalar dependent variable (values of mean reflective, transmission and absorption coefficient ranges) and the independent variable (shade of composite material). All statistical analysis was provided in Microsoft Excel software (Microsoft Office 2016, Microsoft), the calculation of the Concordance correlation coefficient was provided by MedCalc (MedCalc Software).

Results

During conducted study 115 syringes of A1, A2 and A3 shades of Filtek Z250 (3M) – 18 samples, Charisma (Heraeus Kultzer) – 22 samples, i-XCITE LCN (i-dental) – 21 samples, Sagen balance (Crom Dental) – 18 samples, Esterit Sigma Quick (Tokuyama Dental) – 24 samples, Spectrum TPH3 (DENTSPLY) – 12 samples were analyzed. Distribution of composite syringes by the shade were next: A1 (41 eperimental samples), A2 (52 experimental samples), A3 (22 experimantal samples).

96 experimental samples (83,48%) corresponded to the parameters previously registered in formed database of absorption, transmission and reflection in the range of 92,5-96,7% concordance ($P < 0.05$), 10 study samples (8,69%) corresponded to the reference values of 61,8-65,2% concordance ($P < 0.05$), 9 study samples (7,83%) corresponded to the reference values of 33,5-45,6% concordance ($P < 0.05$).

The greatest concordance correlation coefficient of absorption values between referent and study samples among all composites shades and brands was evaluated at wavelength range 500-550 nm (0,9863), 550-600 nm (0,9719) and 800-850 (0,9813).

The greatest concordance correlation coefficient of reflection values between referent and study samples of all shades and brands was evaluated at wavelength range 350-400 nm (0,9916), 550-600 nm (0,9719), 600-650 nm (0,9712) and 800-850 (0,9719).

The greatest concordance correlation coefficient of transmission values between referent and study samples was evaluated at wavelength range 450-500 (0,9874), 500-550 nm (0,9736), 550-600 nm (0,9725) and 800-850 (0,9795).

During analysis it was found that results of comparison transmission and reflective coefficients among reference and study samples were the closest at wavelength range of 550-600 nm and 800-850 nm.

Results of absorption coefficient comparison between referent and study samples were the closest at the range of 500-550 nm, results of reflective coefficient comparison – at the range of 350-400 nm and results of transmission coefficient comparison – at the range of 450-500. Depending on the obtained data, we can state, that evaluation of comparison levels for transmission, reflective and absorption coefficients at the wavelength of 350-550 also can be counted as a criteria of identification, but with less accuracy then at the ranges of 550-600 and 800-850 nm.

No significant association (either linear or curvilinear) was found between tooth shade and a reflective coefficient range ($P > 0.05$) (Table 4). But, some linear and quadratic regression found to be significant between different composites shades and transmission coefficient range, also as between composites shades and absorption coefficient range ($P < 0.05$).

Discussions

The quality of direct composite restorations depends on compliance with a number of criteria, including biological, aesthetic and functional parameters, as well as directly from the quality of the used material. The identification of the composite material physical properties during the clinical trials was described in a study by Jackowski et al.[16], which, however, used for the definition of such indications X-ray density estimation principle by the Hounsfield scale. The author succeeded in developing an approach for the differential evaluation of ceramic and composite materials using the possibilities of rendering tomographic images and numerically representing their difference by the form, density, and topography of composite restorations, but this approach ensures the verification of the physical properties of the composite post-factum – after the making restoration, and thus it is not helping to prevents the emergence of clinical complications associated with inappropriate quality of the material itself.

The study conducted by Ardu et al.[17] described the successful experience of using a reflection spectrophotometer (SpectroShade, Verona, Italy), with the help of which it was possible to determine the indicators of L * (luminosity) a * (quantity of green-red) and b * (quantity of blue-yellow) for enamel and enamel-dentin complex against black and white background. Based on these in vivo data, CR (opacity) and opalescence (the ability to reflect the blue wavelength when white light strokes the object perpendicularly) were also estimated as characteristic of central incisors. The principles of this approach can also be used to verify the optical characteristics of composite restoration on the edge of a healthy tooth, thus providing a numerical assessment of the quality of color selection and the level of composite restoration biomimetic. Such method is to some point analogous to described by authors of this article, but it provides an assessment of other spectrophotometric indices more important for achieving the corresponding aesthetic restoration criteria, but not aimed at the primary identification of composite material of inadequate quality. A similar to Ardu et al.[17] approach was carried out by Hasani-Tabatabaei et al.[18], who conducted investigation of the effects of staining solutions on composite materials by spectrophotometer analysis, but again such approach was not aimed on preventing clinical complication association with dental materials quality.

A number of scientific publications highlighted the importance of used tooth-colored dental filling materials for identifying individuals. At the same time, the authors emphasized that the X-ray method of studying composites restoration is not sufficiently sensitive and needs further improvement. Bush et al.[18] proposed to form the basis for scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM / EDS) of various restoration materials, which could then be used as a benchmark for the identification of materials using portable portable X-ray fluorescence (XRF). This approach differs from others by the fact that previous studies focused on the differentiation of materials of dental and non-dental origin, while the authors focused on the differentiation of just composite materials. The method proposed by the author is now curated by the FBI and is available to the forensics community. However, given the fact that the approach of Bush et al.[18,19] was focused solely on the identification of composite restorations, authors theirselves pointed out, that it can be used in very few cases. In addition, such approach also aimed at post-factual identification of the restoration, and is not characterized by prophylactic orientation of not using composite of non-corresponding quality. In addition, according to Christensen G. J.[11] the presence of a grey market and dental materials that are not attributable to dedicated brands, limits the possibility of the corresponding SEM / IDS identification.

Analogical to proposed method was presented by Suciu et al.[21], who developed a standardized X-ray fluorescence analysis of orthodontic cements with a portable energy-dispersive spectrometer equipped with an anode for an X-ray tube. During the study, it was discovered that XRF analysis demonstrated the relevant aspects in the elemental composition of the orthodontic cements, which are mainly related to unexpected exotic metals in glass-ionomer cements. Thus, the direction of development described by the authors is close to ours, because it involves taking into account the potential complications due to the ingestion of certain trace elements present in the structure of glass ionomer cements. Proposed approach of dental composites identification with the use of original spectrophotometric algorithm differs from all of the above mentioned methods, since it is aimed to the primary identification of composite materials of inappropriate quality. Differences in absorption, transmission and reflection values between reference samples and the subjects allow to detect counterfeits in the market of dental materials, thus preventing the development of potential biologic, aesthetic and functional complications of restoration by excluding the use of such materials.

Due to the obtained results in 15 study composite samples (13,04%) level of concordance between referent and studied absorption, transmission and reflection values was out of the correspond range with sufficient statistical probability ($P < 0.05$). Thus we can conclude that these samples should not be used for composite restoration, because of non-sufficient physical properties registered with spectrophotometric method.

In such conditions, the quality control of dental services should be controlled by a number of relevant competent authorities, experts or commissions formed to address specific application problems in the relevant controversial situations. Partly the issue of assessment and quality control of dental services is set out as a subdiscipline of forensic dentistry, which solves the issue of developing an applied methodology of quality criteria evaluation and theoretical concepts of identifying persons by dental changes. In Ukraine, the issue of quality control of composite restorations is realized in close cooperation with the Association of Forensic Dentistry, and is included in the Association's broader task by the assessment the quality of dental services provided to the population[21,22].

Conclusions

The use of the proposed spectrophotometric algorithm for identifying composite materials physical properties allowed to verify the correspondence between the reference samples and the study samples with 92,5-96,7% concordance in 83,48% cases. Such results help to expand the objective evidence base of the criteria for assessing the quality of dental care provision, which also can be used during forensic medical examinations. Proposed approach also helps to prevent the use of composite materials with non-sufficient physical properties registered with spectrophotometric method, samples of which could be presented at the grey market and objectively non attributed to any manufacture's brand.

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