Bioceramics Development and Applications
ISSN: 2090-5025
Mazurek et al., Bioceram Dev Appl 2015, 6:1
DOI: 10.4172/2090-5025.100087
Research Article
Open Access

The Absorption of the Curing Light Intensity by the Ceramic Material Used for Porcelain Veneers

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Abstract

Introduction: Porcelain veneers are widely used in aesthetic prosthetic restoration of teeth in the anterior region. The application of dental porcelain facilitates obtaining excellent, natural-looking results with minimum invasive preparation of the tooth tissues. From both the mechanical and the aesthetic point of view, the strength and the durability of an adhesive bond depends on the correct conditioning of the luted surfaces and the polymerization procedure resulting in a high monomer conversion rate in the cement.

Aim: The aim of this study was to measure the absorption of the intensity of curing light passing through samples of feldspar ceramic of various colors and thicknesses.

Materials and methods: The study used disc-shaped samples prepared from Feldspathic porcelain. The diameter of each disc was 9.0 mm and their thickness ranged from 0.8 mm to 2.1 mm. Discs were prepared in different shades. The curing light intensity was measured for polymerization device Blue phase LED lamp (Ivoclar Vivadent, Liechtenstein) at a 1200 mW/cm^2 light intensity (± 10%) and a wavelength ranging from 380 to 515 nm. Light intensity was measured using power gauge FieldMax (Coherent, USA).

Results: Based on the measurements performed, it can be concluded that curing light intensity transmission decreases exponentially with the increase of the ceramic layer thickness. The results obtained indicated that the increase in color intensity and the decrease in ceramic brightness result in a reduction of the curing light transmission.

Conclusion: To achieve adequate polymerization of the composite material placed beneath the restoration layer, the curing time should be adjusted according to the specified parameters.

Keywords: Dental cavities; Light intensity; Photoinitiator; Tooth tissue; Teeth discolouration

Introduction

Ceramic veneers are a restorative solution to rehabilitate lost hard tooth tissues in the anterior region. Indications for bonded porcelain restorations include: teeth resistant to bleaching, morphologically altered teeth, drug-induced tooth discolouration and erosions. Indications for veneers have expanded to include special cases of aesthetic reconstruction of non-vital teeth, in the management of crown fractures in teenagers and in patients with deep bite and insufficient space on the palatal surface of the tooth for a traditional crown. Veneers can also be applied in patients with extensive class V cavities (according to Black) [1,2]. The perfect functional and aesthetic effect obtained with ceramic veneers depends on the type of the ceramic material, its colour, surface characteristic and specific, individual features of the restored tooth. Two types of ceramic materials, i.e., feldspar and pressed ceramic, are currently most frequently used to manufacture ceramic veneers. Both of these materials contain a large amount of glass phase which guarantees high translucency, and mimics the light effects of the natural tooth [3,4]. The level of translucency of the ceramic material depends on its thickness, the number of burning cycles and the content of the crystalline phase. Heffernan observed that all types of ceramic materials showed reduced opaqueness after covering with a glaze layer. It still remains unclear whether this effect is secondary to the additional smoothing layer or the higher number of porcelain burning cycles [5]. Expectations of both the dentists and the patients are aesthetic satisfaction, durability and function of the prosthetic restorations comparable to those of natural teeth. Thus, apart from trying to achieve a perfect aesthetic result of the prosthetic restoration, which mimics natural dentition, it is necessary to ensure appropriate and durable bond to the tooth surface. The bond should be resistant in time to the unfavourable environment of the oral cavity. From both the mechanical and the aesthetic point of view, the strength and the durability of an adhesive bond depend on the conditioning procedures of the luted surfaces and the polymerisation mode resulting in a high monomer conversion rate in the cement. According to Fan et al., the polymerisation rate of composite materials depends on the chemical composition of the cementing material and concentration and the type of photoinitiator [6]. On the other hand, the depth of polymerisation in the composite material is determined by the curing light intensity, beam width, wavelength and curing time. Incorrect polymerisation of the composite material reduces its physical properties such as mechanical durability, water sorption and hardness. It also decreases its aesthetic parameters [7]. Composite material manufacturers usually recommend a specific curing time and optimal curing light intensity to obtain the correct material setting, yet individual conditions of each patient's oral cavity often require adjustment of the above mentioned parameters. Therefore, the aim of this study was to measure the absorption of the intensity of curing light passing through samples of feldspar ceramic of various colours and thicknesses.

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Received November 17, 2015; **Accepted** December 11, 2015; **Published** December 21, 2015

Citation: Mazurek K, Kamiński W, Warda P, Mierzwińska-Nastalska E, Szczyrek P (2015) The Absorption of the Curing Light Intensity by the Ceramic Material Used for Porcelain Veneers. Bioceram Dev Appl 6: 087. doi:10.4172/2090-5025.100087

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Materials and Methods

The absorption of the curing light intensity was measured for Vita Omega 900 feldspar ceramic (phosphate) (VITA Zahnfabrik, Germany). Fifteen samples of ceramic material in different colours and thicknesses were included into the study. Fifteen disc-shaped samples, measuring 9.0 mm in diameter and 0.8, 1.6 or 2.1 mm in thickness were prepared from Vita Omega 900 feldspar ceramic (VITA Zahnfabrik, Germany). The samples were prepared in the following shades: "Window", B1, B2, A3, and A4 in accordance with the Vitapan shade guide (VITA Zahnfabrik, Germany). Discs were polished on one side with the use of All Ceramic Finishing & Polishing Kit and Dura Polish DIA wax (SHOFU INC., Japan) just as veneers made of feldspar porcelain are polished. The curing light intensity passing through the layer of feldspar ceramic was measured for the Bluephase LED lamp (Ivoclar Vivadent, Liechtenstein) working at a wavelength range between 380-515 nm. Light intensity was measured using power gauge FieldMax (Coherent, USA). During the measurements, the ceramic samples were fixed on the end of the coherent optical fibre bundle of the lamp. The location and distance of the polymerisation device from the gauge head were identical at each measurement so that the light beam leaving the ceramic disc fell directly on the reading field of the measuring head. Every sample was reversed with the glazed/polished surface to the output of the light-curing unit.

Results

When analysing the measurements we assumed an exponential light intensity reduction with increasing sample thickness. This allowed for calculating approximate intensity values for other sample thicknesses than those used during measurements, ranging from 0.8 to 2.15 mm for feldspar ceramic. Also, the study revealed the influence of ceramic material colour on the curing light intensity transmission. The samples with high colour saturation and low brightness (A3, A4) transmitted less light than brighter samples with low colour saturation. The results obtained present a correlation between light transmission of the polymerisation device and ceramic material thickness and colour. The measurement results were presented as proportional values in relation to the curing light intensity which was 1200 mW/cm^2 (Figure 1). Graphic presentation of the results indicates that the feldspar ceramic "Window" (W) sample, i.e., enamel layer, presents the highest light transmission, up to 90%, for a sample thickness of 0.8 mm and decreases to 70% for a sample of 2.0 mm thickness. In order to achieve the correct polymerisation rate of the cementing material, the reduction of the light intensity, resulting from beam transmission via the ceramic layer, should be compensated by the appropriate prolongation of the curing time. It is possible to determine the curing time prolongation ratio which indicates how much the curing time should be prolonged depending on the thickness and colour of the ceramic restoration (Figure 2). The table present specific values of the curing time prolongation ratio for various thicknesses and shades of the studied ceramic material (Table 1).

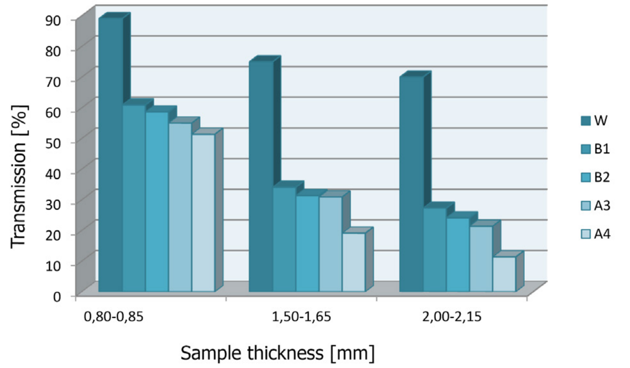

Figure 1: The proportional values of curing light intensity transmission for samples of Vita Omega 900.

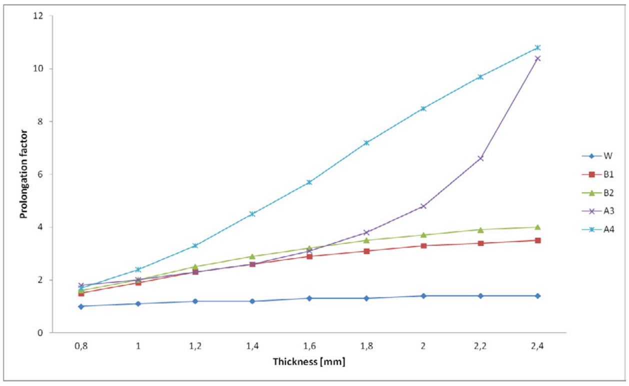

Figure 2: The correlation between curing time lengthening ratio and ceramic thickness for feldspar ceramic samples.

Discussion

The durability and long-term aesthetics of ceramic veneers are mainly dependent on the durability of the adhesive bond between the cement and both the restoration and the abutment tooth [8]. The bond strength and durability of the composite material are determined by its polymerisation rate, which is 50-75%. This value is sufficient to achieve satisfactory aesthetic and mechanical properties [9]. According to J.F. Roulet, a durable adhesive bond requires not only appropriate impregnation of the tooth tissue by the bonding system and reduction of bond permeability, but also optimisation of the polymerisation rate of the bonding resin, which allows for avoiding polymerisation shrinkage and therefore phase separation (separation of the bonding system from the cement layer) [10]. The available literature supports the importance of the polymerisation process during adhesive cementing. As a result, it should be taken into account that each factor reducing the polymerisation rate negatively influences the durability of the bond between the veneer and the tooth [4]. The chemical composition of the composite material includes organic resin, inorganic filler and polymerisation photoinitiator (camphorquinone), which initiates the polymerisation process in the presence of light at a wavelength of 470 nm [11]. For luting veneers, it is recommended to use light-curing composites with no chemical component, and consequently every factor reducing polymerisation rate negatively influences the bond quality. There is no chemical bond substitute to create better bond [12]. The main problem arising when bonding ceramic veneers is the absorption of the light intensity by the ceramic layer, which reduces the amount of light reaching the cement layer and bears upon the polymerisation rate and, in consequence, the quality of the bond between the restoration and the tooth. The following factors directly influence the polymerisation process of the composite material: the structure of the ceramic material, its colour and thickness, the output light intensity of the polymerisation device and the curing time [9,13]. The reported studies allow for the calculation of the light intensity absorbed by the ceramic layer, which in turn enables the approximate determination of the polymerisation rate of the composite material (cement) placed beneath the restoration layer,

Colour	Thickness (mm)								
	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4
W	1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.4
B1	1.5	1.9	2.3	2.6	2.9	3.1	3.3	3.4	3.5
B2	1.6	2.0	2.5	2.9	3.2	3.5	3.7	3.9	4.0
A3	1.8	2.0	2.3	2.6	3.1	3.8	4.8	6.6	10.4
A4	1.7	2.4	3.3	4.5	5.7	7.2	8.5	9.7	10.8

Table 1: The values of prolongation factor for ceramic material Vita Omega 900.

depending on its thickness and colour. Most of the research articles focus on the mechanical properties of the luting agent polymerized beneath ceramic layer, like: Vickers Hardness and modulus of elasticity [14]. Performing these study researchers focused only at the amount of light energy passing through ceramic layer without taking into account the type and characteristic of composite lutnig material, just to determine the proper exposure time. The translucency of the ceramic material is determined by its thickness, crystal structure and firing conditions. Ceramic materials with high content of the glass phase, including feldspar ceramic, are characterized by high translucency, which means that light-curing cements are recommended for bonding of restorations manufactured from these materials. The permeability of this type of ceramic is sufficient for the proper polymerisation of the light-curing cement, even for 2 mm thick ceramic layers in bright colours, which is confirmed by conducted study. Darker shades and thicker layers (A4 thickness >2 mm) demand extending the curing time even 10 times. Clinically it is impossible to light-cure the cement for 4-6 minutes in oral cavity, because of high temperature creation which is very dangerous for pulp vitality. In such cases Ozyesil et al., recommend the use of the polymerisation device with higher output light intensity (LED) for cementing ceramic restorations due to their lower curing time [7]. Another way is to use dual-cured cement in cases of fixing restorations of high saturation of color, low brightness or layer above 2 mm to compensate (chemical polymerization component) for the insufficient light polymerization [4,15]. Clinically the most important is the knowledge of ceramic material properties because the type of material influences the most Light transmission. The most translucent of dental ceramics is feldspar ceramic, which even through thick layers transmits large amount of light – up to 90%. Using feldspar ceramic the prolongation is usually one curing time period more than cement manufacturer's recommendations. Another thing is the colour and its intensity. When clinical situation demands aesthetic reconstruction of teeth discolouration's, stains, bleaching resistant teeth or pulpless teeth the high intensity of the colour of the reconstruction should be chosen to hide the defects. Feldspar ceramic restorations higher intensity which means the use of ceramic mass higher opacity, demand extending the curing time period twice and more relative to manufacturer's recommendations. Clinically ceramic opacity depends on the thickness and reflectance of the basic dentin layer [16]. Before the calculated ratio values are introduced into clinical practice, a careful consideration should be given to the fact that the study was performed in *in vitro* conditions and the raise in the temperature during cement polymerisation was not taken into account. It should also be borne in mind that the measurements were performed in ideal laboratory conditions. The samples had constant thickness and were flat shaped, the direction of the light propagation was perpendicular to the sample surface and the lamp was tightly fitted to the samples. In real-life conditions, the light intensity reduction may be increased by additional factors such as inaccurate fitting of the active surface of the lamp to the restoration surface or light dispersion on the border between the veneer and cement. For the above-mentioned reasons, it should be considered that in clinical practice the curing time prolongation should be more significant than could be inferred from the presented measurement results. The transmission is further influenced by the polishing technique of the external surface of the ceramic veneer, which aims at receiving the most enamel-like look possible. Veneers manufactured using feldspar ceramic are polished until an appropriate gloss is obtained. It obviously results in different reflection ratios of veneer surface and thus different amounts of transmitted light.

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