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Strength and thickness of the layer of materials used for ceramic veneers bonding

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The use of adhesive bonding systems and composites in prosthetic dentistry brought improved and more aesthetic prosthetic restorations. The adhesive bonding of porcelain veneers is based on the micromechanical and chemical bond between tooth surface, cement layer and ceramic material. The aim of the study was to measure the thickness of the material layer formed during cementing of a ceramic restoration, and – in the second part of the study – to test tension of these cements.

The materials investigated comprised dual-curing materials: Variolink II, KoNroot Cem, KoNroot Cem Viscous and Panavia F 2.0, as well as a light-curing composite: Variolink Veneer. The thickness was measured with the use of ZIP Lite 250 optical gauging apparatus. SEM microscope – Hitachi Tabletop Microscope TM-100 – was used to analyse the characteristics of an adhesive bond and filler particle size of particular materials. Tension tests of the cements under study were carried out on the MTS Q Test 10 static electrodynamic apparatus.

The tests showed that KoNroot Cem exhibited the best mechanical properties of bonding to enamel and dentin among the materials tested. Variolink II base light-curing cement formed the thinnest layer. All the materials tested formed the layer not exceeding 1/3 of ceramic restoration thickness.

Key words: *cement strength, cement layer thickness, ceramic veneers*

1. Introduction

Ceramic veneers are prosthetic restorations which allow a permanent change of the patient's teeth aesthetics: their colour, shape, position in the arch. A distinct value of such restorations is minimal preparation of tooth hard tissues. Due to the use of ceramic materials and non-invasive preparation they are well accepted by periodontal tissues and they perfectly imitate natural dentition [1].

The rapid development in the area of ceramic prosthetic restorations began in the 1980s. At that time, adhesive bonding systems and luting cements began to be widely used. Their effect relies on forming micromechanical and chemical bond between the tooth surface, cement and restoration surface. Yet, at that time, ceramic veneers had a high failure rate due to imperfection of particular restoration elements. They were primarily related to quality, aesthetics and mechanical features of the ceramic material, bonding systems and luting cements, as well as to the procedures of conditioning the surfaces involved in the adhesion [1].

Current knowledge and experience of dentists allow very thin ceramic veneers to be made which guarantee an excellent long-term aesthetic effect. Treatment outcome depends on the following key

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factors: proper material selection, depth of preparation ensuring resistant adhesive bond, carefully conducted clinical conditioning of bonded surfaces, perfect fit between the restoration and the abutment tooth as a prerequisite of a uniform and thin cement layer, as well as possibly high degree of cement polymerization [1]–[3].

The study aimed at evaluating the thickness of the layer formed by the cements used to bond the ceramics to the tooth tissues and at measuring tangent tension of the materials tested.

2. Materials and methods

Layer thickness tests were used to measure specifically prepared specimens of luting cements representing the materials used in ceramic veneers bonding, including: Variolink II, Variolink Veneer (Ivoclar Vivadent, Liechtenstein), KoNroot Cem, KoNroot Cem Viscous (GDF GmbH, Germany) and Panavia F 2.0 (Kuraray Medical Inc, Japan). The prepared specimens imitated a ceramic restoration bonded to the tooth surface. The extracted molars were prepared using a P600 grit abrasive paper in order to form flat and polished surfaces. Afterwards, 1-mm thick Empress 2 ceramic discs were cemented using the above-mentioned luting cements and Syntac Classic bonding system (Ivoclar Vivadent, Liechtenstein). Later on, longitudinal sections of the samples were made, which were subjected to SEM microscope analysis (Hitachi Tabletop Microscope TM-1000). Then, precise thickness measurement was performed with ZIP Lite 250 optical gauging apparatus.

The second test measured tension within the above-mentioned cements with the use of the MTS Q/Test 10 static electrodynamic apparatus. Extracted premolars and molars were used to craft the specimens. The roots were embedded in methacrylate resin blocks. The coronal parts of the teeth were prepared with P600 grid corundum abrasive paper until a flat and smooth surface was obtained. The teeth surfaces prepared were divided into two groups: I – enamel, II – dentine. Ceramic specimens (4 mm in diameter, 2 mm in thickness) were then cemented to the tooth surface using the above-mentioned materials. The test was carried out in accordance with the ISO TS 11405 standard for adhesive material testing at the Material Resistance Laboratory of the Faculty of Materials Science and Engineering, Warsaw University of Technology. The apparatus cross-beam traverse was 0.75 mm/min. The total of 97 tension tests were conducted, 10 per each cement bonded to enamel and 10 per each cement bonded to dentine.

3. Results

According to the test results, the thickest layer of 129 μm was formed by KoNroot Cem cement, which exhibits dual curing mechanism. Figure 1 presents one section of the sample of KoNroot Cem material. The thinnest layer of 15 μm was formed by Variolink II base cement. Only the base of Variolink II system was used, which maintained the properties of light-curing material. Test results are presented in table 1.

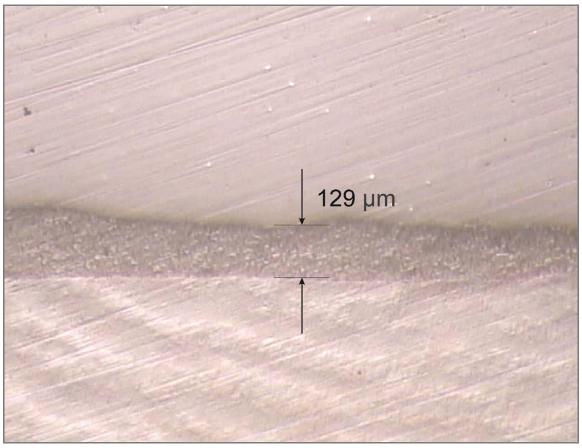

Fig. 1. Measurement of the KoNroot Cem cement layer thickness using ZIP Lite 250 optical gauging apparatus

Table 1. Cement layer thickness [μm]

KoNroot Cem		KoNroot Cem Viscous		Variolink Veneer		Variolink II		Variolink II base		Panavia F 2,0	
min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
49	129	32	79	33	49	34	101	15	54	41	80

During the SEM microscope analysis, the size and shape of filler particles were observed as well as the existing areas of leakage in the form of air between the tooth surface and the bonding system (figure 2). The image shows the ceramic-to-dentin bond obtained with the use of KoNroot Cem Viscous cement with

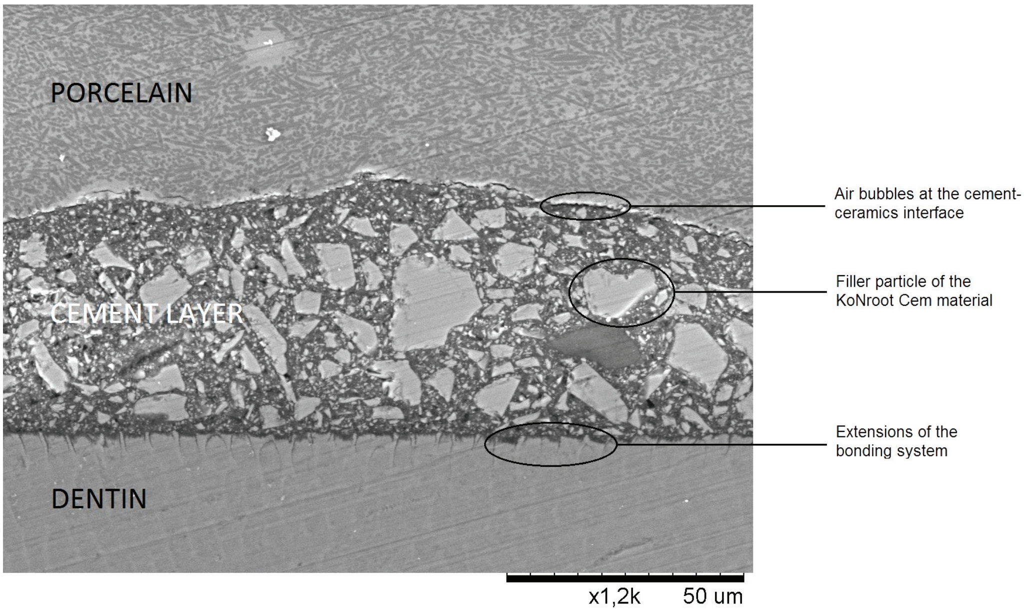

Fig. 2. SEM image of KoNroot Cem Viscous cement

Table 2. Tension test results for tested materials bonded to enamel and dentin

Cement	Tooth surface	Mean tension values [MPa]	Standard deviation	Maximum tension values	Minimal tension values
Panavia F 2,0	E	11.23	5.3	19.18	5.3
Panavia F 2,0	D	7.83	3.3	15.94	4.08
Variolink II	E	13.03	6.5	23.69	3.48
Variolink II	D	9.13	5.1	18.05	1.9
KoNroot Cem Viscous	E	18.89	5.2	25.04	11.37
KoNroot Cem Viscous	D	5.22	2.5	10.54	1.33
Variolink Veneer	E	14.42	5.8	25.25	5.44
Variolink Veneer	D	8.80	2.5	12.58	3.79
KoNroot Cem	E	21.87	8.1	32.56	11.1
KoNroot Cem	D	9.48	3.7	15.25	4.22

D – dentin, E – enamel.

silicon dioxide nanoparticles. One can notice the extensions of the bonding system penetrating into dentin area as well as the air bubbles at the cement-ceramics interface.

Tension values for particular materials tested are presented in table 2. KoNroot Cem cement demonstrated the highest mean tension of the bond to enamel – 21.8 MPa, as well as to dentin – 9.5 MPa. The weakest bond to enamel was formed by Panavia F 2.0 – 11.23 MPa, while the lowest mean tension (5.22 MPa) of the bond to dentin was demonstrated by KoNroot Cem Viscous with silicon dioxide nanoparticles. KoNroot Cem bond to enamel showed a wide range of measurement results from 11.1 MPa to 32.56 MPa (standard deviation 8.1), nonetheless it obtained the highest mean tension values. The variance of the tension values for bonding to dentin was clearly lower as compared to enamel bonding.

4. Discussion

The cement layer thickness test showed that the thinnest layer was formed by light-curing low viscosity Variolink II base material. It is characterised by good aesthetic properties, such as stability of colour and possibility to match cement colour to the colour of the restoration [4], [5]. Therefore, it seems reasonable to use it while cementing ceramic veneers in cases where the margin of a preparation is located within enamel in order to ensure adequate mechanical strength.

The data available in the literature indicate that in order to obtain proper distribution of forces in the case of cementing ceramic veneers, an appropriate thickness ratio of cement layer to ceramics is important [4]. Preferably, the cement layer thickness should constitute no more than 1/3 of ceramic thickness [1]. All the materials tested met this condition.

KoNroot Cem Viscous with silicon dioxide nanoparticles is characterised by the highest viscosity, however, it is not ranked among the materials which form the thickest layer. This might suggest that decreased filler size (resulting in nanoparticles) improves its mechanical properties.

The material exhibiting highest tension values – KoNroot Cem – is a dual-curing cement. The mechanical properties of the bond to enamel as well as to dentin give it the most advantageous characteristics. Taking into consideration the self-curing component, which is responsible for gradual degradation of cement colour, it is not recommended to use this material in the case of thin ceramic restorations [6], [7]. It should be borne in mind that veneer thickness of up to 1.0 mm and its high translucency warrant proper polymerization of the luting cement, allowing the use of light-cured material. In the case of higher thickness of restoration or its increased colour saturation, the chances of good polymerization drop drastically and the use of dual-curing material should be considered [1], [7]–[9].

Another important factor affecting bond strength is the type of tooth tissue with which the bond is formed: enamel or dentin. Definitely lower tension values were obtained in bonding to dentin, as demonstrated in the present study and in numerous scientific reports [3], [4], [10]. Optimal tooth preparation for ceramic veneer should be limited to enamel and the thickness of ceramic material should remain within 0.3–0.9 mm range [1]. Fulfilment of the above-mentioned conditions allows a long-term aesthetic effect to be achieved.

5. Conclusions

1. According to the study results, KoNroot Cem cement exhibited the best mechanical properties of bonding ceramics to enamel and dentin among the materials tested.

2. All the cements tested, regardless of the curing mechanism or filler particle size, form an adequately thin layer in the case of bonding ceramics to dentin.

3. Tooth preparation for ceramic veneers requires a reasonable material choice, reflecting the depth of abutment tooth preparation, ceramics type, mechanical and aesthetic features of the cement as well as the properties of the applied bonding system, which plays a key role in bonding to dentin.

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