Evaluation of the Adhesion of a Novel Design of Veneers to Dental Materials

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The aim of this in vitro study was to assess a new design that, to our knowledge, we have introduced (patent pending) for indirect dental veneers. Their effect on the retention and adhesive properties at their interfaces have been studied. Fourteen high performance polymeric (PEEK) dental veneers have been elaborated using a computer-aided-design (CAD) software and then milled using a computer-aided-machine (CAM). They were divided in two experimental groups: seven classical veneers with a liniar marginal contour and seven dental veneers with the novel proposed sinusoidal marginal design. All the samples have been bonded to polymeric blocks that had the vestibular face prepared in a specific way for each group. The values of the retention and adhesive forces were tested in vitro by applying bending forces on the incisal edge of the veneers, from the oral to the vestibular direction. A 50% increase of the values of these forces for the novel design with regard to the classical one has been demonstrated through the study.

Keywords: dental veneers, sinusoidal contour, retention, adhesion, aesthetic dentistry, Computer-aided-design (CAD), Computer-aided-manufacturing (CAM)

Aesthetic dentistry has become one of the most popular fields of nowadays dentistry, as beauty represents one of the best trigger for a young and healthy appearance. Thus, dentists have to satisfy the patients' high expectations. Indirect dental veneers and the wide range of highly esthetic dental materials that are developed are a method to meet these expectations.

Since the bonding of the first ceramic dental veneer in 1930 by Dr. Charles Pincus, thousands of experimental studies have been conducted in order to enhance both mechanical and cosmetic properties. Despite the numerous studies, in literature only a certain, classical appearance of these prosthetic treatment options has been considered, with a liniar contour, i.e. a straight and sheer contact with the adiacent dental structure [1]. Although this liniar design has the advantage of simplicity, it has the major drawback of a small contact surface with the adiacent enamel, and also the large amount of sound tooth removal [2, 5]. As a consequence of the former, the retention itself is due mainly to the mechanical properties of the dental adhesives.

Chemical adhesion no longer represents a drawback in the long-term dental treatments, since considerable enhancements have been brought to the components and clinical properties of dental adhesives. Therefore, the adhesion of composite resins to the etched enamel exceeds nowadays 20 MPa, which is a good value for ensuring optimal retention and less marginal percolation of most restorative procedures [6]. However, one always wants to augument adhesive forces; this can be achieved using several methods: (i) by increasing the enamel surface aimed to interact with the resin; (ii) by exposing the organic part of the enamel; (iii) by clearing the superficial structures of the enamel and, last but not least; (iv) by displaying highly polar phosphate groups on the enamel surface [7].

Refering to the latter measure, the enamel bonding agents represent a mixture of base monomers (Bis-GMA) and dilution monomers (TEGDMA), which is applied on the freshly etched and dried enamel surface. After the polymerization of the bonding agents, two types of resin filaments are formed: macrofilaments (in the centre or at the periphery of the prisms) and microfilaments (in each and every disolved hydroxyapatite crystal) [8]. The adhesion to the enamel is micromechanical. The monomers of enamel bonding agents copolymerize with the monomers of the organic phase of the composite resins, giving birth to chemical covalent reactions. The resistence against shear forces of bonding agents/ composite resins and enamel, with values between 18 and 22 MPa, depends on the thickness of bonding agent and the shear strenght of the etched prisms [9]. At these high bond strengths, most of the bond failure modes have been cohesive in dentin.

As a remark, for measurements of interfacial bond strength, new testing methods are necessary; a new, microtensile method for such measurements was described along with the preliminary results, in [10].

The aim of this paper is to tackle with the debonding of the indirect dental veneers due to the classical liniar marginal contour – issue (i) in the above discussion. In order to find a tehnical solution to this particular problem, we have developed a sinusoidal marginal design which is expected to display three major advantages: (a) higher retention due to the marginal micro-intrications between the dental structure and the dental veneer, (b) higher adhesion due to larger superficial contact at the interface, and (c) a more accurate positioning of the veneers *in situ* during the luting procedure. This of dental veneer, subject of a recent patent request of our group [11], has not been

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described in the literature before, to the best of our knowledge.

Experimental part

The experimental study has been carried out on 14 veneers, which were divided in two groups, depending on the type of tooth preparation: Group 1: 7 classical (CL) veneers and Group 2: 7 crenelated (CR) veneers, of our proposal [11] (fig. 1). The latter, crenelated preparation of the teeth consists of three sinusoidal marginal lines which outline the contour of the facial dental veneer; the proximal limits of the latter are positioned just before the interdental contact. The height of the crenelated lines is corelated with the type of the tooth, namely: 2-2.5 mm for the lateral incisors and inferior central incisors, and 2.5-3 mm for the central upper incisors and for the canines. The depth of the sinusoidal proximal margins decreases progressively from 0.6-0.8 mm in the gingival third, to 0.4-0.6 mm in the middle third, and to 0.3-0.4 mm in the incisal third. The facial face of the tooth is reduced by 0.5-0.8 mm and the incisal margin by 1 mm in order to provide an aesthetic final restoration.

This CR dental veneers has a specific design that fits with the particular preparation of the tooth: three sinusoidal proximal margins with different heights and depths, 0.5-0.8 mm facial thickness and 1 mm incisal thickness.

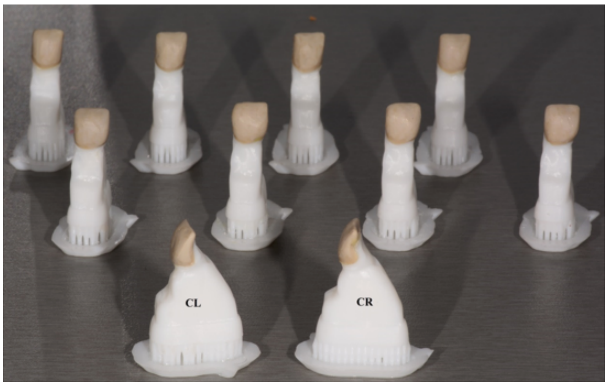


Fig. 1. Ten out of the fourteen experimental veneers divided in two experimental groups: Group 1, represented by a classical veneer (CL,left) and Group 2, represented by a crenelated veneer (CR, right)

The technological process of designing and manufacturing of the CR veneers has been throughly based on Computer-aided-design (CAD) and on Computer-aided-manufacturing (CAM). Firstly, the crenelated preparation has been performed on a gypsum cast by a dental tehnician; this cast has been afterwards scanned with 3 SHAPE DENTAL SCANNER. Then, the margins of the preparations have been accurately outlined by using the CAD-software 3 SHAPE DENTAL DESIGNER. Once the design of the preparation has been established, it was immediately exported in 3 SHAPE MODEL BUILDER, which is a CAD software for designing a virtual model from a previous scan. Thus, an accurate tridimensional (3D) model has been obtained (fig. 2).

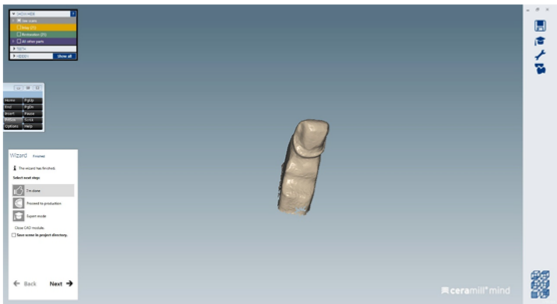


Fig. 2. 3D SHAPE MODEL BUILDER - CAD software for designing a virtual 3D model

The STL file containing the virtual model has been then exported to PREFORM SOFTWARE; its role is to prepare the models for printing on FormLabs printer, therefore it gives the specialist the freedom to focus on the creative process. This software auto-oriented, supported and layed out the model for optimal results. The 3D model of the crenelated preparation has been consequently printed by using FORM 2, which is the most advanced existing 3D printer. At the heart of this machine is an optical engine with a precision laser with a power of 250 mW that is guided by custom-built galvanometer scanners [12], delivering large prints with good resolutions. After a 6 h printing process, the 14 printed resin models obtained were cleaned with isopropyl alcohol and then photopolymerized for several minutes (fig. 3).

Fig. 3. Printed resin model of a classical dental veneer preparation

The next technological step has been to elaborate the 14 dental veneers to fit with the 14 preparations displayed on the printed models, namely 7 for CLl veneers and other 7 for the CR ones. The STL files containing the virtual 3D models created by 3SHAPE MODEL BUILER have been exported to the CERAMILL MIND design software (Amann Girrbach), in order to define the final design of the dental veneers. Thus, the software allowed the dental tehnician to precisely outline the marginal contour, both on the external and on the internal surfaces, the cement gap (0.08 mm), the friction on the dental surface (0.3 mm from margin), and the overall design (figs. 4 and 5).

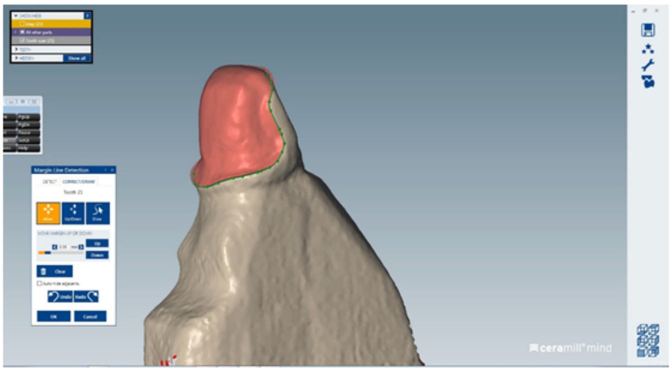


Fig. 4. CERAMILL MIND – design of the marginal contour of the

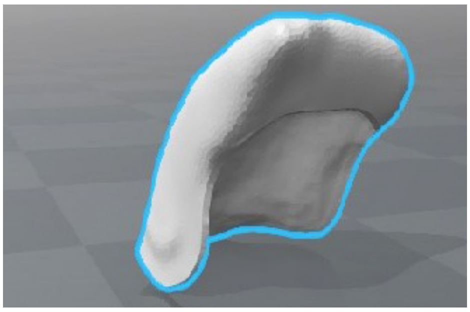


Fig. 5. CERAMILL MIND – development of the 3D design of the crenelated (CR) veneer

Once all the details have been set, the information has been transferred to CERAMILL MATCH 2, which is a CAM software that facilitates the positioning of the virtual prosthetic restorations into the virtual blanks. The blank has been selected from a digital library and the selected material was CERAMILL PEEK, which is a performant polymer for the digital fabrication of removable and fixed restorations (e.g., crowns, bridges, secondary and telescope restorations, or attachment restorations). Specially developed for the CAD/CAM techniques, this material is based on a high-performance PEEK polymer with proven biocompatibility, which ensures its long-term use. The last step of the manufacturing of the dental veneers has been the milling process performed using CERAMILL MOTION 2, which works with a range of indications and in-house materials. Its 5-axis milling unit combines wet and dry processing and allows for the creation chain to be kept in-house in the laboratory.

The 14 polymeric dental veneers manufactured by milling the peek blanks have been then luted to the prepared facial surface of the 14 polymethylmethacrylate blocks by using a dental universal adhesive (Scotchbond Universal Adhesive 3M ESPE), as well as a dual-curing flowable core build-up and a post luting system (Rebilda DC, VOCO). Both the internal surfaces of the veneers and the facial surfaces of the preparations were previously conditioned using a sandblasting procedure (fig. 6).

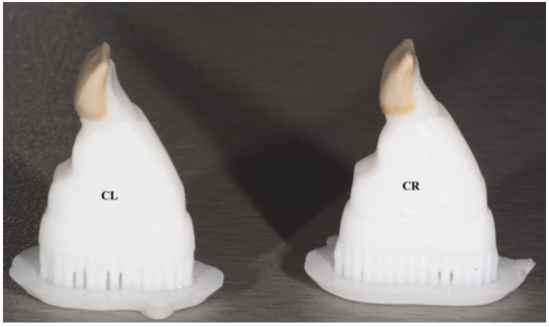


Fig. 6. The classical (CL, left) and the crenelated (CR, right) dental veneers luted to the printed polymethylmethacrylate blocks

As the purpose of the research was to assess the difference between the two groups in terms of mechanical resistance against detachment [13], bending forces have been applied on the incisal margins of the veneers. The tests were performed in displacement control at 1 mm/min, on a universal testing machine Zwick/Roell Z005 (fig. 7), which has the following characteristics: 5 kN load in tensile/compression, accuracy class 0.5, crosshead speed from 0.0005 to 1500 mm/min, ±1 μm maximum error in differential movement measurement between two measuring points in a range from 20 to 200 μm. The machine was equipped with tensile grips, the test setup and data post-processing being performed using the TestXpert II software.

Fig. 7. Universal testing machine Zwick/Roell Z005

The adhesive joint strength of the veneered teeth was evaluated by means of single cantilever bending, the load being applied on the veneer edge, as presented in figure 8 (up). In order to facilitate the clamping, the teeth were imbedded in epoxy resin (fig. 8). The debonding (fig. 8, down) of the veneer is well-marked in the force-displacement curve by the sudden drop of the force.

Fig. 8. The direction of the bending force applied to the incisal edge of the veneer (top) and its consequent detachment (bottom)

Results and discussions

Some representative force-displacement curves for the two types of adhesive joints (classical (CL) and crenelated (CR), respectively) are presented in figures 9 and 10. The maximum force values recorded at failure are presented in table 1. The CL veneers (Group 1) have failed by applying an average force of 48.70 ± 14.57 N, whereas a higher mean value was observed for CR joints (Group 2), namely 133.26 ± 41.23 N. The relative increase, equal to +63.46 %, clearly demonstrated the superiority of the CR group. The veneered teeth bonded joints failed for both types in an adhesive mode, with the adhesive remaining on the teeth surface.

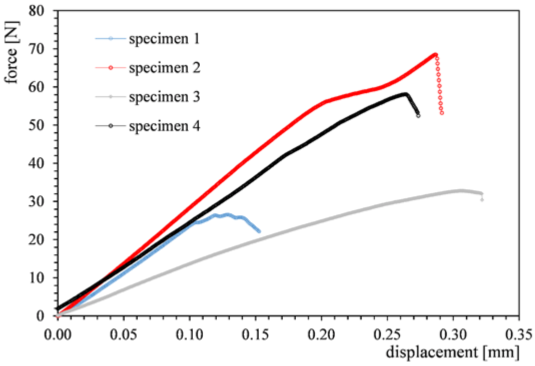


Fig. 9. The force-displacement curve of the classical joint (CL, Group 1)

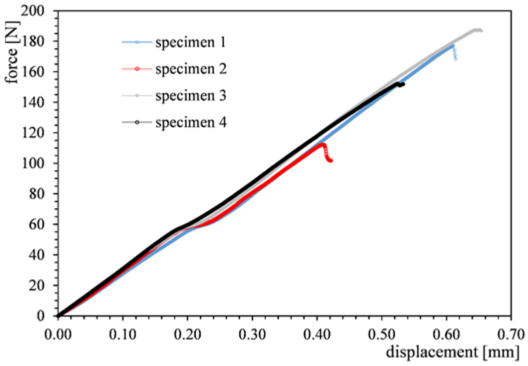
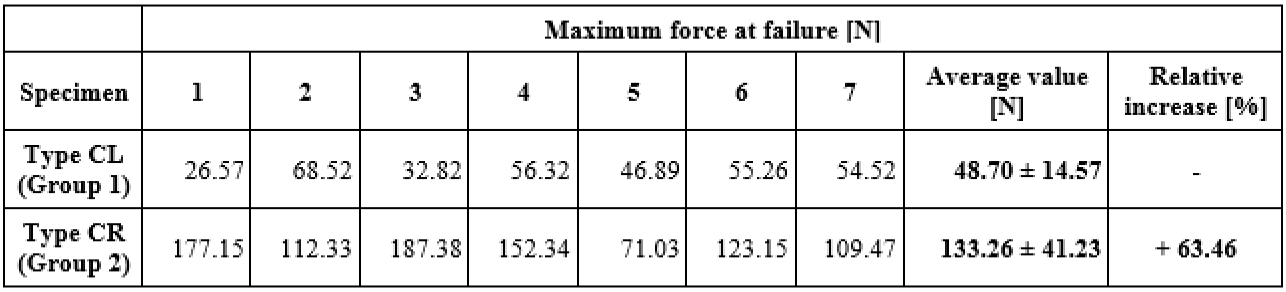


Fig. 10. The force-displacement curve of the crenelated joints (CR, Group 2)

Table 1
THE MAXIMUM FORCE VALUES RECORDED AT FAILURE FOR BOTH EXPERIMENTAL GROUPS: GROUP 1 - CLASSICAL (CL); GROUP 2 - CRENELATED (CR)



	Maximum force at failure [N]								
Specimen	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Average value [N]**	**Relative increase [%]**
Type CL (Group 1)	26.57	68.52	32.82	56.32	46.89	55.26	54.52	**48.70 ± 14.57**	-
Type CR (Group 2)	177.15	112.33	187.38	152.34	71.03	123.15	109.47	**133.26 ± 41.23**	**+ 63.46**

Taking into consideration that both groups have been prepared for the experimental test by using the same protocol (design, manufacturing, sandblasting, luting, and loading), the higher adhesive forces displayed by the crenelated veneers seem to be closely related to the design of the marginal contour, which is important in creating the micro-retentions at the periphery of the preparation.

Conclusions

The crenelated (CR) veneers have not been described in the literature before, to the best of our knowledge, and they were proposed for a patent by our group [9] as a practical solution to augment the adhesive and mechanical properties of dental veneers. The results obtained in this study show that such CR joints are superior in comparison with classical (CL) joints, leading to the sheer conclusion that the new design of the veneer preparation has several advantages:

Increases the adhesive forces by more than 60%, thus decreasing the probability of veneer detachment;

Produces higher retention forces due to the peripheral micro-retentions that form an intricated joint between the veneer and the substrate;

Provides better contact on the surfaces, thus combining both adhesive and mechanical forces that prevent the veneer debonding;

Assures a more accurate positioning of the veneers *in situ* during the luting procedure.

Therefore, our *in vitro* research demonstrated that the CR veneers represent a successful long-term treatment option in aesthetic dentistry and that their longevity is mainly due to their sinusoidal contour and peripheral intrications with the substrate. Future work includes clinical researches in order to evaluate their adhesive and mechanical properties *in vivo*, during the masticatory and other functional loads.

Acknowledgement: This research was partially supported by the Romanian National Authority for Scientific Research through CNDI–UEFISCDI Grant PN-III-P2-2.1-PTE-2016-0181 (http://3om-group-optomechatronics.ro/). C. Sinescu acknowledges the support of the PIII-C2-PCFI-2015/2016 project – UMF Victor Babes Timisoara

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Manuscript received: 23.03.2017