Bond strength of dual – cured resin cements to a glass infiltrated alumina ceramic
Resistência de união entre cimentos resinosos duais à uma cerâmica aluminizada infiltrada por vidro

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Abstract

The present study evaluated the union resistance among the surface of the ceramic In Ceram Alumina® (Vita Zahnfabrik, Bad-Säckingen, Germany) and two different types of resin cements (Panavia F, Kuraray® e Relyx, 3M®). Six ceramics blocks were made with dimensions of 6x6x5mm following the technical guide lines wich were duplicated in composite resin (W3D MASTER®). One of the faces of the ceramic block (6mmx5mm) was sandblasted with the Rocatec system® and cemented with the two different cements under constant load of 750g to the correspondents faces composite blocks. After the storage of the samples (seven days in distilled water at 37º) each group formed by ceramic, cement and resin was split up in two axis X and Y and it were obtained specimens with adehive area of 1mm² ± 0,1. Two groups (n=27) were obtained: PanaviaF group and RelyX group. Each sample was fixed with cyanocrylate in an adapted device which was attached to a universal testing machine (EMIC) and then subjected to tensile forces at a crosshead of 0.5 mm/min and load cell of 10kgf. The results showed that the medium values of rupture (MPa) for the PanaviaF group (median=30.98 ± standart deviation=5.43) are statistically different comparing to RelyX group (median 12.48 ± standart deviation 3.54) (p-value=0.,001). The conclusion of this study was that the Panavia F had better adhesive resistance than RelyX. All fractures analyzed occurred at the adhesive zone, with no findings of cohesive fracture of the porcelain.

Key words

Resin cements; tensile strength, ceramic

Introduction and Literature Review

The increase in the demand of patients and professionals interested in esthetic restorations that may reproduce the natural dentition led many investigators and the industry to develop ceramic materials more resistant than the conventional porcelain-fused-to-metal restorations for utilization without the metallic framework. Thus, since mid 1990s, investigators and clinicians have been searching for new options for the fabrication of all-ceramic restorations that present qualities of strength, color stability, longevity and accurate fit for utilization in any area of the dental arch.

The ceramic system for framework In Ceram, (Vita Zahnfabrik, Bad-Säckingen, Germany) described by Sadoun in 1994 is a system that utilizes a sintered crystalline matrix of a high-modulus material that is characterized by a junction of the particles in a crystalline phase. The framework is then infiltrated with a low-viscosity lanthanum glass at a high temperature to enhance its flexural strength (MCLAREN & WHITE, 2002[12]).

Besides the intrinsic strength of the porcelain, the bonding procedure between it and the tooth structure is an important factor for the longevity of the ceramic restoration. Therefore, its internal surface must be susceptible to a treatment, the aim of which is to yield micromechanical retentions to allow the adhesive systems (bonding agent and resin cements) to be as effective on the ceramics as they are on the tooth structure.

Neither etching with hydrofluoric acid or silane coupling can provide a reliable bond between alumina ceramic with low silica content and resin cements. The reason is the compact surface of ceramics with high alumina content, which – in contrast to glass based ceramics – resists degradation by acids. In Ceram Alumina, because of the high amount of alumina (ca 80wt%), is one such material[19]. Thus, an effective alternative for the treatment of the internal surface of this ceramic system is the sandblasting with silica particles (Rocatec), followed by application of silane. This method of silica deposition on the ceramic surface by the Rocatec system was introduced by Guggenberger [8] in 1989, who indicated the fast accomplishment of the surface treatment and the direct observation of the silica layer as the main advantages of this system.

Valandro et al. [18] (2004) evaluated the microtensile strength of a resin cement applied to a ceramic substrate in three conditions of surface treatment. Six blocks of In-Ceram Alumina ceramics (Vita) and six blocks of composite resin (Clearfil APX, Kuraray) measuring 6mmx6mmx5mmm were prepared. The ceramic surface was abraded with sandpaper grits n. 800, 1000 and 1200 under cooling, and the blocks were divided into three groups according to the surface treatment: Group 1 – microsandblasting with 110-µm aluminum oxide (Micro Etcher, Danville); Group 2 – Rocatec system (ESPE): sandblasting with 110-µm aluminum oxide (Rocatec Pre–powder) and with silica (Rocatec – Plus powder) + Rocatec – Sil; Group 3 – CoJet system (ESPE – 3M): sandblasting with 30-µm silica particles + ESPE – Sil. The ceramic blocks were cemented to the composite resin blocks with the resin cement Panavia F (Kuraray Co.) following the manufacturer's instructions, under a 750-g load for ten minutes. The specimens were stored (distilled water at 37°C for seven days) and sectioned along two axes, x and y, with a diamond disc under cooling (Labcut 1010) in order to achieve specimens with ± 0.8mm^2 of bonding area (n=20). The specimens were attached to a device adapted for the microtensile testing and assessed (at a speed of 0.5mm/min) in a universal testing machine EMIC. The results achieved (MPa) for the study groups were as follows: Group 1 – 17.77; Group 2 – 31.33; and Group 3 – 33.33. Analysis of the results obtained revealed that Groups 2 and 3 displayed higher bond strength than Group 1, with no different between Groups 2 and 3.

The cementation procedure plays an important role for the longevity of the prosthetic rehabilitations, completing a series of steps on which each procedure contributes to a successful treatment.

The bonding compatibility between the aluminized ceramic and the resin cements was investigated by Friederich & Kern [7] (2002) as to the methods of surface etching and thermocycling/storage. For that purpose, ceramic specimens (discs measuring 7.5mm in diameter) were submitted to the following treatments after being microsandblasted (JAT) with 110-µm Al_2O_3 particles (pressure of 2.5bars for 13 seconds, at a 10-mm distance: Rocatec pre):

a) resin cement Twinlok (BisGMA based);
b) silane + Twinlok;
c) Rocatec system + silane + adhesive system + Twinlok;
d) Rocatec system + Panavia 21 Ex;
e) Panavia 21 Ex cement.

An acrylic cylinder measuring 3.2mm in diameter and 15.5mm in height was filled with self-curing composite resin. After 8 minutes, the assembly was bonded to the pretreated ceramic by the aforementioned cements, under a 750-g load, followed by removal of the excess cement and light-curing. Thereafter, the six groups were divided in two subgroups, according to the period of storage (37°C) and thermocycling between 5°C – 55°C (TC): three days without TC; 150 days with 37,000 TC (150/TC); and then submitted to the microtensile testing (2mm/min). The values (MPa) obtained for the respective groups were as follows: Group 1 – 19.7; Group 2 – 18.0; Group 3 – 20.3; Group 4 – 50.3; Group 5 – 23.0. After the 150-day period of storage and thermocycling, all specimens in Groups 1, 2, 3 and 5 debonded spontaneously, whereas those in Group 4 kept a stable bonding. Utilization of the resin cement with 10 MDP in the Panavia 21 Ex group yielded higher bond strengths after storage for three days and 150/TC (50.3MPa and 45.9MPa, respectively). There was a reduction in bond strength, yet not statistically significant. Groups 1 and 2 displayed adhesive failures, Group 3 had predominantly adhesive failures (81%) in the specimens stored for three days and adhesive failures in the specimens stored for 150/TC; 100% of cohesive failures were observed in the specimens in Group 4 for both conditions of storage, and Group 5 had an increase of adhesive failures in the specimens stored for 150/TC. Even though the aluminized ceramic has a low silica content (5%) and high alumina content (80%), deposition of silica on the surface associated to the application of silane by the Rocatec system allowed the achievement of a high bond strength between the ceramic and the resin cements, even after 150 days. The good outcomes found in Group 4 were assigned to the phosphate monomer MDP contained in the Panavia 21 EX cement.

Leite et al.[10] (2003) evaluated the union resistance among the surface of the ceramic In Ceram Alumina® (Vita Zahnfabrik Bad-Säckingen, Germany) and two different types of resin cements (Panavia F, Kuraray® e Relyx, 3M®).Two ceramic blocks were made with dimensions of 6x6x5mm following the technical guide lines wich were duplicated in composite resin (W3D MASTER®). One of the faces of the ceramic block (6mmx5mm) was sandblasted with the Rocatec system® and cemented with the two different cements under constant load of 750g to the correspondents faces composite blocks. After the storage of the samples (seven days in distilled water at 37º) each group formed by ceramic, cement and resin was split up in two axis X and Y and it were obtained specimens with adehive area of 1 mm² ± 0.1. Two groups (n=27) were obtained: PanaviaF group and RelyX group. Each sample was fixed with cyanocrylate in an adapted device which was attached to a universal testing machine (EMIC) and then subjected to tensile forces at a crosshead of 0.5 mm/min and load cell of 10kgf. The results showed that the medium values of rupture (MPa) for the PanaviaF group (median=17.011 ± standart deviation=4.131) are statistically different comparing to RelyX group (median 10.071 ± standart deviation 3.550) (p-value=0.001). The conclusion of this study was that the Panavia F had better adhesive resistance than RelyX. All fractures analyzed occurred at the adhesive interface, with no findings of cohesive fracture of the porcelain.

The search for a truly adhesive bonding between a restorative material and a substrate demands the accomplishment of an assessment to test the mechanical bond strength, such as the microtensile testing. The specimens employed for this test must have a minimum surface area, what theoretically yields a more uniform distribution of the stress by the material. The microtensile testing is advantageous because it allows the occurrence of adhesive failures when an average area of $1mm^2$ is tested, assessment of small areas and easy measurement of the adhesive area; improves the evaluation under scanning electron microscopy and yields reliable clinical outcomes because of the uniform application of forces on the material evaluated (PASHLEY et al. [15], 1995).

The following hypothesis was tested in the present study: does the MDP-modified resin cement present higher bond strength to an aluminized ceramic surface than a conventional resin cement?

Material and Method

Six ceramics blocks of In Ceram Alumina (Vita Zahnfabrik, Bad-Säckingen, Germany) measuring 6mm in thickness, 6mm in height and 5mm were made according to the manufacturer's instrusctions.

The internal structure of each ceramic block was submitted to radiographic evaluation, by means of periapical radiographs, for observation of possible defects inside its mass (e.g. bubbles). The presence of internal defects led to exclusion of the specimen from the study.

The surface selected for bonding (5mmx6mm) was manually flattened under constant wetting with water, by means of sandpaper grits n. 600, 800, 1000 and 1200 (DELLA BONA et al.[5], 2000). These steps allowed a more uniform contact between the ceramic surface and the composite resin block surface after cementation.

Thereafter, each ceramic block was bonded with cyanoacrylate adhesive (Super Bonder, Loctite) to a metallic device attached to a mechanical sectioning machine (ANDREATTA FILHO et al.[1], 2003) for cutting of each ceramic block along its length in three segments measuring 5mmx6mmx6mm. Sectioning was performed with steel diamond discs (22-mm diameter, 0.15-mm thickness, ref. 7016, KG Sorensen, Sao Paulo, Brazil) at low speed on a handpiece (Kavo Ind.e Com. Ltda) connected to the mechanical sectioning machine, under proper water cooling. This way, each group comprised three ceramic blocks that were randomly assigned to the study groups.

Impressions were achieved from each ceramic segment (untreated) in heavy-body addition silicone (Express, 3M Co., St. Paul, MN – USA), inside a plastic recipient with the bonding surface downwards, so as it was impressed in the impression material, as well as the entire ceramic segment. After curing of the impression material, each ceramic segment was removed from the addition silicone and composite resin (W3D Master, RJ, Brazil) was condensed inside the impression achieved, with 2-mm increments light-cured for 40 seconds each (XL 3000 – 3M Dental Products, St. Paul, MN – USA), with a light intensity of 450mw/cm^2, up to complete filling of the impression, yielding a polymer specimen (5mmx6mmx6mm) for each ceramic segment (KERN & THOMPSON [9], 1995). Thus, the composite resin bonding surface had the same design as the bonding surface of the ceramic segment.

The previously determined and prepared surface of the ceramic blocks (6mmx5mm) was treated with the Rocatec system (ESPE, Seefeld – Germany): microsandblasting with 110-µm aluminum oxide particles: Rocatec pre-powder; microsandblasting with special silica particles mixed to 110-µm aluminum oxide particles: Rocatec-plus powder; silanization: Rocatec-Sil.

Each ceramic block was bonded to the corresponding composite resin block with the resin cement Panavia F and RelyX. Each cement was prepared following the manufacturer's instruction and applied on the treated surface of each ceramic segment.

After positioning of the ceramic-cement-resin assembly in a hydraulic press under a 750-g load (LEITE et al. [10], 2003) for 10 minutes, the excess cement was removed, light-curing was performed for 40 seconds on each margin of the adhesive line with a light-curing unit (XL 3000 – 3M Dental Products, St. Paul, MN – USA) with a light intensity of 450 mw/cm^2, and the blocks cemented with Panavia F received application of an Oxyguard layer on all external margins of the adhesive interface up to 10 minutes for final cementation. The ceramic-cement-resin assemblies were washed with an air/water spray and stored in distilled water at 37°C for seven days, up to preparation of the specimens, modified from Kern & Thompson [9], 1995; Awliya et al. [2], 1998.

Sectioning was performed with steel diamond discs (22-mm diameter, 0.15-mm thickness, ref. 7016, KG Sorensen, Sao Paulo, Brazil) at low speed, under proper water cooling, on a handpiece (Kavo Ind.e Com. Ltda – São Paulo – Brazil) connected to the mechanical sectioning machine calibrated for the x and y axes, with possibility of sectioning in both directions (ANDREATTA FILHO et al. [1], 2003), of the Department of Dental Materials and Prosthodontics of Sao Jose dos Campos Dental School.

Initially, the ceramic-cement-resin assemblies were bonded with a cyanoacrylate adhesive (Super Bonder, Loctite™,São Paulo, Brazil) to a cylindrical metallic base, which in turn was connected to a clamp of the sectioning machine. Each ceramic-cement-resin assembly should necessarily be perpendicular to the diamond disc (ref. 7016, KG Sorensen, Sao Paulo, Brazil) for the achievement of sections as regular as possible, leading the thickness of the slices achieved to be homogeneous. After calibration of the sectioning machine, repeated after every sectioning procedure, the first section was performed for elimination of part of the extremity of the specimen (±0.5mm) because of the risk of permanence of excess cement (*flash*) around the adhesive interface, which would directly influence the microtensile strength values. Afterwards, three sections were performed on the ceramic-cement-resin assembly, yielding slices measuring 1±0.05 mm^2 in thickness.

One of the first slices was turned 90° and once again attached to the metallic base. The first section eliminated the extremity of the specimen (±0.5mm) for the same aforementioned reason. Further three sections were achieved, also measuring 1±0.05mm^2 in thickness. This same process was followed for the other two slices, adding up to new specimens for each two bonded blocks of ceramic-resin, and therefore the groups comprised 27 "sticks" (n=27). All microspecimens displayed the following characteristics: a) rectangular shape; b) square transverse section – symmetric, c) adhesive area of 1±0.05 mm^2; d) length of ±10mm (ANDREATTA FILHO et al.[1] 2003; SHONO et al.[17], 1999; DELLA BONA et al.[6], 2000; LEITE et al.[10], 2003; VALANDRO et al.[18], 2004).

Each slice was positioned with its 10x1mm surface towards the metallic device and bonded to it with the cyanoacrylate adhesive (Super Bonder, Loctite, Brazil) for the accomplishment of further sections and achievement of "stick"-shaped specimens.

For the microtensile testing, each specimen was bonded with cyanoacrylate adhesive (Super Bonder, Loctite) to the caliper clamps, with the adhesive interface perpendicular to the force applied, in order to reduce the presence of torsion forces at the adhesive area (BIANCHI[3], 1999). Just the extremities of the specimen were employed for fixation, so the adhesive area was kept within the space between both the two of the device. The caliper-specimen assembly was attached to a universal testing machine EMIC LD 1000 and assessed at a speed of 0.5mm.min^{-1} until failure occurred.

The area of all specimens was measured before testing with a digital caliper (Starret Industria e Comercio Ltda, Itu, SP, Brazil) to the nearest 0.01mm. The area, as well as the load required for failure, were employed for calculation of the tensile bond strength (MPa), which was calculated by the following formula: S_b=F/A, where: S_b is the bond strength, F if the force applied, and A is the ceramic/cement/resin bonding area.

After accomplishment of the tension strength testing, the surfaces of the 54 specimens were examined under a stereoscopic microscope (light microscope ZEISS MC 80 DX – Tecnival Carl Zeiss – JENA) with 50x magnificatino for establishment of the pattern of failure on the interface between ceramic and resin cement.

Results

Table 1 – Descriptive statistics of the data (MPa) obtained in the microtensile testing

Statistics	Panavia F	Rely X
N	27	27
Mean	30.98a	12.48b
Standard deviation	4.13	3.55
C.V (%)	24.28	35.25
Minimum	10.22	7.21
Median	16.60	9.46
Maximum	28.81	23.94

* Different superscript letters mean statistical difference

The bond strength values (MPa) obtained were analysed by t(*Student*), α=0.05. The statistical test allowed rejection of the hypothesis of equality between the mean values of microtensile strength (t= 14.84; gl=52; p= 0.001).

The resin cement Panavia F (mean ± standard deviation, 30.98 ± 5.43MPa) displayed higher bond strength than the resin cement RelyX (mean ± standard deviation, 12.48 ± 3.54 MPa).

Results of Light Microscopy

The results related to evaluation of the failure patterns under a stereoscopic microscope (light microscope ZEISS MC 80 DX – Tecnival Carl Zeiss – JENA) with 50x magnificatino in the specimens submitted to the microtensile testing demonstrated that in all 54 specimens there were 100% of failures in the adhesive zone.

Discussion

There are several studies on the literature on the optimization of bonding by different surface treatments between adhesive resin cements and composite resins or conventional ceramics (AWLIYA et al. [2], 1998; MC LEAN [13], 2001; DELLA BONA et al. [6], 2002). However, even though most aluminized ceramics restorations are bonded with resin cements, little information has been reported on the bond strength between the treated surface of these ceramics and the resin cements. Thus, this study was conducted to evaluate the bonding between the aluminized ceramic for framework of In Ceram Alumina™, submitted to surface treatment with the Rocatec system, and two different resin cements: MDP-modified cement (Panavia F) and a conventional BisGMA-based cement (RelyX).

Selection of the microtensile testing for assessment of the bond strength between the materials investigated was based on several conclusive studies that demonstrated its effectiveness and reliability for evaluation of the adhesive bond strength to the tooth and ceramic structures (SANO et al.[16], 1994; DELLA BONA et al.[5], 2000). Moreover, many studies in the literature indicate the possibility of achievement of several specimens from a small structure, either a restoration bonded to a human or bovine tooth, for example, or small ceramic and resin blocks bonded to each other such as in the present study, as the main advantage of the microtensile testing (SANO et al.[16], 1994; PASHLEY et al.[15], 1995; YOSHIAMA et al.[20], 1998; ANDREATTA FILHO et al.[1], 2003; LEITE et al.[10], 2003; LOPES et al.[11], 2003; VALANDRO et al.[18], 2003).

The authors (SANO et al. 16, 1994; YOSHIAMA et al. 20, 1998; SHONO et al. 17, 1999; SUDSANGIAM & VAN NOORT 19, 1999) agree on the ability of actual evaluation of the bond strength between different substrates provided by this testing, since it allows evaluation of small areas (about 1mm2) of a same adhesive surface, inducing less intrinsic failures in the adhesive bonding (because of the small area of evaluation) and providing a larger number of adhesive failures after fracture instead of cohesive or mixed failures. However, assessment of the failure mode in the present study revealed the presence of mixed failures with predominance of the adhesive component. Some hypotheses might explain this fact:

a) as regards the materials that compose the adhesive area, the resin cement is the most likely to display internal defects (bubbles). Thus, there would be concentration of stresses in these areas and initiation and propagation of fractures through these defects;
b) presence of torsion force. However, this could not be demonstrated, since no evaluation of the distribution of stresses with finite element analysis has been conducted.

However, there was a concern to:

a) position the adhesive line as perpendicular as possible to the tensile force (BIANCHI 3, 1999; SHONO et al. 17, 1999; ANDREATTA FILHO et al. 1, 2003; LEITE et al. 10, 2003; LOPES et al. 11, 2003; VALANDRO et al. 19, 2003);
b) attach the specimens as parallel as possible to the long axis of the testing device, considering its parallel guide;
c) position the device as parallel as possible to the application of tensile load on the universal testing machine in order to induce predominantly tensile forces on the interface during testing.

In the present study, special attention was directed to the mode of cementation of the ceramic/composite blocks as to the amount and mode of load applied. Cementation was performed under a static and constant load of 750g for 10 minutes, what provided a uniform thickness of the cement layer (KERN & THOMPSON 9, 1995; ANDREATTA FILHO 1 et al., 2003; LEITE et al. 10, 2003; LOPES et al. 11, 2003; VALANDRO et al. 18, 2004).

A solution to this problem of surface treatment of the aluminized ceramic for cementation with a resin cement would be the utilization of the Rocatec system, which comprises the application of by three chemical treatments. Several investigations have demonstrated satisfactory bond strength values of aluminized ceramics treated with this system (KERN&THOMPSON 9, 1995; BLIXT et al. 4, 2000; ÖZCAN et al. 14, 2001; VALANDRO et al. 18 2004), therefore suggesting that this is an effective and stable method for adhesive cementation.

The resin cements evaluated in the present study presented different compositions: MDP-modified cement (Panavia F) and conventional BisGMA-based cement (RelyX). The higher mean values of tensile bond strength observed for the Panavia F group (17.011MPa) compared to the RelyX group (10.071MPa) may be explained by the following mechanisms: 1) creation of a micromorphological pattern that allows micromechanical bonding to the resin cement, besides increasing the wettability of the ceramic surface; 2) chemical union between silica, silane and the resin material 9 and chemical union between the phosphate monomers MDP and the aluminum oxide 21.

The bond strength values achieved on the microtensile testing under both bonding conditions proposed could not be compared to the findings of other authors because of the lack of studies in the literature with the same direction, even though similar reports have analyzed other types of ceramic systems under different conditions of cementation, surface treatments and aging conditions .

As regards the analysis of the images achieved by light microscopy, all fractures analyzed occurred at the adhesive interface, with no findings of cohesive fracture of the porcelain. This afirmation is compatible with the information found in the literature, which state that the adhesive microtensile testing would yield more adhesive or mixed fractures than the conventional bond strength testings, which yield many cohesive fractures (SANO et al. 16, 1994; PASHLEY et al. 15, 1995; SHONO et al. 17, 1999; DELLA BONA et al. 5, 2000).

The results achieved in the present study revealed that the microtensile testing was effective for evaluation of the bond strength of the two resin cements, allowing the proposal of further studies addressing other resin cements. All steps required for the accomplishment of an indirect restoration are fundamental for its longevity. The cements investigated point out a better performance of the Panavia F cement, even though it is recognized that the individual characteristics of each material lead to specific indications.

Conclusion

After analysis and discussion of the outcomes, and considering the methodology employed in the present study, the following could be concluded:

a) there was a statistically significant difference between the two resin cements evaluated;
b) the MDP-modified resin cement Panavia F presented a higher mean bond strength (30.98MPa) than the BisGMA-based resin cement RelyX (12.48MPa).

Resumo

O presente estudo avaliou a resistência da união entre a superfície da cerâmica In Ceram Alumina® (Vita Zahnfabrik, Bad-Säckingen, Germany) e dois cimentos resinosos (Panavia F, Kuraray® e RelyX, 3M ESPE®). Foram confeccionados seis blocos da cerâmica para infra-estrutura In Ceram Alumina com dimensões de 6mm x 6mm x 5mm (recomendações do fabricante), os quais foram duplicados em resina composta (W3D MASTER, Wilcos, Brasil). Uma das faces de cada bloco cerâmico (6mm x 5mm) foi tratada com o sistema Rocatec (ESPE, EUA) e cimentada com os dois cimentos resinosos, sob carga constante de 750g, à face do bloco de resina composta correspondente. Passado o período de armazenagem (água destilada por sete dias à 37°C), cada conjunto formado por cerâmica,cimento e resina foi seccionado no sentido X e Y, obtendo-se amostras com área adesiva de 1 mm² ± 0,1. Dois grupos (n=27) foram constituídos : grupo do Panavia F e do Rely X. Cada amostra foi fixada com cianoacrilato num paquímetro adaptado e acoplado em máquina de ensaios universal (EMIC) com célula de carga de 10kgf e velocidade de 0,5mm/min. Os dados (MPa) foram submetidos ao teste estatístico paramétrico "t" de amostras independentes cujos resultados indicaram que o grupo do Panavia F (média = 30,98MPa ; dp = 5,43) diferiu estatisticamente (p-valor = 0,001) do grupo do RelyX (média = 12,48; dp = 3,54). Pela análise dos resultados conclui-se que o Panavia F apresentou melhor resistência adesiva do que o RelyX. Todas as falhas ocorreram na zona adesiva, não sendo observada nenhuma falha coesiva na cerâmica.

Unitermos

Cimentos de resina, resistência à tração, cerâmica.

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