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Micromorphology of the fiber post–resin core unit: a scanning electron microscopy evaluation

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Summary *Objectives*. To microscopically evaluate the structural characteristics of post-and-core units made with a fiber post and different types of composite resins used as build-up materials. *Materials and methods*. Forty endodontically treated human maxillary incisors were prepared for receiving a fiber post (Aesthetic Post Plus, RTD). One-Step (Bisco) was used as a bonding material, and C&B resin cement (Bisco) for luting the post. The posted roots were randomly divided into eight groups. In each group a different material or technique was applied to build up the abutment. The materials on trial were Z100 (3M-ESPE), Lumiglass (RTD), Gradia (GC), Build-it! (Jeneric Pentron). On the specimens of Groups 5–8, the same materials were used for build-ups, with the addition of a preshaped plastic shell (Composipost, Core Form, RTD). All the post-and-core specimens were cut perpendicular to their long axis and processed for SEM observation. The objective was to detect the presence of voids/bubbles within the resin abutment, and of gaps at the interface between the post surface and the core material. These aspects were quantified with reference to indexes. The differences among the scores were tested for statistical significance ($p < 0.05$). *Results*. In the absence of any matrix, cores built up with Gradia showed the highest integrity, and those made with Z100 the best adaptation onto the post. In the presence of shells, Build-it! provided the most satisfactory result. Build-it! was the only material to perform better when used in combination with a shell. *Significance*. When hybrid composites are used to build up a core onto a fiber post, a higher homogeneity of the abutment and a better post-core integration are achieved if the build up is done in the absence of any matrix.

Introduction

It often happens that teeth meant to serve as abutments in fixed prostheses are extensively destroyed as a result of caries, trauma, or previous restoration. In the face of a conspicuous horizontal loss of the clinical crown, such that only a ferule of minimal thickness could be created in the remaining tooth structure, a post-and-core build-up is needed.[1–3] In particular, the described clinical situation has traditionally been regarded as a specific indication for a cast gold post-and-core.[3]

However, some alternatives to cast posts and cores have been developed over recent years, such

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as the use of prefabricated posts in combination with composite resins to directly build-up the core. This technique offers the advantages of simplifying chairside procedures. In addition, the use of new tooth-colored fiber posts[4,5] in combination with a matching resin-based material for core build-up, is expected to yield a more natural and esthetic appearance of the final restoration, as compared with a cast post-and-core.[5] As regards mechanical properties, cores directly built-up with composite resin have shown a fracture resistance comparable to that of cast gold cores.[6-9]

For building up the abutment after luting a fiber post, all the types of composites, from the microhybrids[10-12] to the flowables[13,14] in the light-activated or the self-curing formulation, could virtually be used. These materials differ among themselves in terms of strength, stiffness or elasticity, and other properties that can affect the longevity of the final restoration.[14,15]

The question as to the type of composite that performs best in directly building up a core on a posted tooth has not yet been systematically addressed.

Furthermore, preshaped shells have recently been marketed, which are claimed to speed up and simplify the procedure of building up the abutment. However, it has not yet been verified whether the addition of this matrix as a support in composite layer stratification actually results in improved structural integrity of the abutment, or in enhanced adaptation of the core material around the post.

The method of scanning electron microscopy has already been applied to investigate the morphologic characteristics of post-and-core units made of resin-based materials.[14] In the present study, scanning electron microscopy was used to get an insight of the structural homogeneity of cores made up of different composite resins, with and without the support of preformed shells, as well as to assess the degree of structural continuity between the build-up material and the post. More precisely, the study was aimed at detecting and quantifying the presence of voids/bubbles and gaps, both within abutments made with and without preshaped shells, and at the interface between the post and the build-up material. It tested the null hypothesis that different restorative materials and build-up techniques cannot determine the morphological differences of the abutments.

Materials and methods

Forty human maxillary incisors selected for the study were placed, immediately after extraction, in a physiologic solution, where they were kept for the whole experimental period. Only sound teeth with an average length of 23 ± 1 mm were included in the sample.[16]

Endodontic treatment was performed through stepwise filing with reamers and Handstrom files to Int. Standard Organization size 60. A 2.5% sodium hypochlorite solution was used to deterge the root canals, which were finally obturated with laterally condensed guttapercha and a resin sealer (AH plus; De Trey, Kostanz, Germany). With a diamond bur mounted on a high-speed handpiece and used under continuous water cooling, the teeth were decoronated 2 mm coronally to the most incisal point of the cementum-enamel junction (CEJ), and sectioned perpendicularly to the long axis of the tooth. On all of the teeth a 2 mm butt shoulder finishing line was prepared. Guttapercha was removed from the root canals with a Largo drill, leaving 4 mm of root canal filling in the apical portion. Several drills provided in a kit together with the posts were used in the recommended sequence to prepare the canal for post-insertion.

Then, in each tooth a fiber post (Aesthetic Post Plus, St Egeve, France) was placed. In order to bond the post to the root canal walls, the dentin at this level was etched with 36% phosphoric acid, rinsed after 15 s, and dried with paper points. The One-Step adhesive system (Bisco, Schaumburg, IL, USA) was applied as a bonding material, and the C&B resin cement (Bisco) was used to lute the post. The post surface was silaned with silane (Bisco) for 5 min. All of the materials were handled according to the manufacturers' instructions.

Composite core build-up

The specimens were randomly divided into eight groups of five teeth each.

On the posted roots, composite cores were built up to reach an abutment height of 6 mm, as measured from the buccal CEJ. Two millimetres of material created a ferule on the dentin substrate, whereas the remaining 4 mm of composite actually made up the abutment. In each group of teeth a different composite resin was tested as a core build-up material. Three hybrid composites, Z100 (3M-ESPE, Group 1), Lumiglass (RTD, Group 2), and Gradia (GC, Tokyo, Japan) were compared to Build-it! (Jeneric Pentron, Wallingsford, CT), a fiber-reinforced dual-cure material, specifically developed for core build-ups (Group 4).

In the specimens of Groups 5-8, a preformed shell (Composipost Core Form, RTD, St Egeve, France) was placed onto each posted root. According to the dimensions of the residual tooth portion, a shell of appropriate size was chosen for each specimen. The shell was then completely filled with a composite resin, the excess material was removed, and the resulting abutment was light-cured through the transparent shell with a Visilux light unit (3M-ESPE, St Paul, MN, USA). The light was irradiated on the buccal, lingual, mesial, and distal aspect of the shell, each time for 40 s. The same four composites used to build up the cores in the absence of any matrix, were also tested in combination with the preformed shells. They were Z100 (3M-ESPE, Group 5), Lumiglass (RTD, Group 6), Gradia (GC, Group 7), Build-it! (Jeneric Pentron, Group 8).

The materials were always used strictly following manufacturers' instructions.

The cores built up without any shell (Groups 1-4) had to be slightly prepared to make their shape apt to support a hypothetical crown, whereas the abutment built up within the shells (Groups 5-8) already presented with an adequate shape.

On all of the abutments a 1-2 mm butt shoulder was prepared, and a wall convergence of approximately 6° was created.

Then, the specimens were cut perpendicularly to their long axis 1-, 2- and 3 mm from the top of the abutment. Each section was gold sputtered with an Edwards Coater S150B device, mounted on a metallic stub, and observed under a Philips 505 Scanning Electron Microscope at different magnifications. The presence of voids/bubbles within the abutments, as well as the finding of gaps at the post-core interface were recorded, and scored according to indexes thus defined.

Scores within the abutment: 0, no voids/bubbles; 1, few voids/bubbles of a small size (100-200 μm); 2, voids/bubbles of a size between 200 and 500 μm; 3, voids/bubbles of a size between 500 μm and 2 mm; 4, voids/bubbles larger than 2 mm (Fig. 1).

Scores at the adhesive interface: 0, no gaps; 1, gap no longer than 200 μm; 2, gap between 200 and 500 μm; 3, gap between 500 μm and 1 mm; 4, gap longer than 1 mm (Fig. 2).

The sections were separately observed by two investigators. In case of a disagreement between the two investigators on the score assigned to a certain specimen, the worse score was chosen for the statistical analysis.

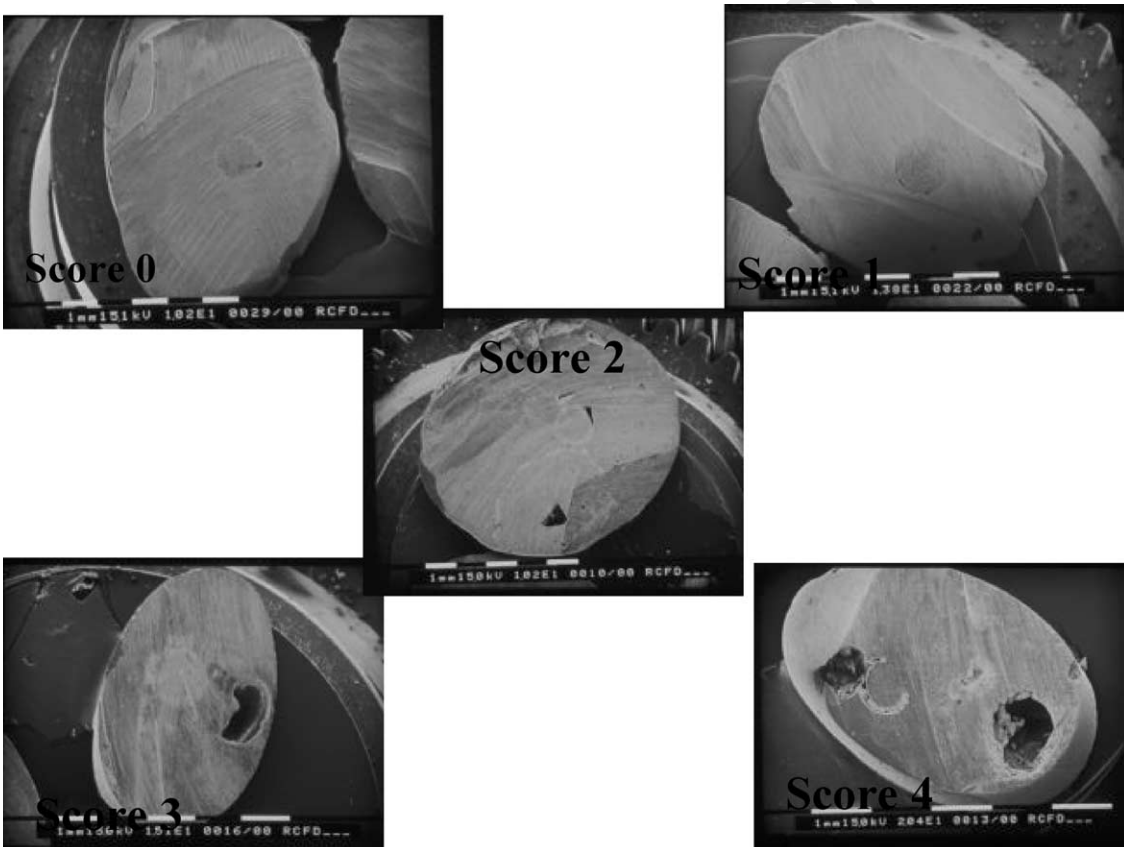

Figure 1 Abutment scores. (a) Score 0: no voids/bubbles are detectable within the abutment. (b) Score 1: only few voids/bubbles of a small size (100-200 μm) are visible. (c) Score 2: voids/bubbles of a size between 200 and 500 μm are present. (d) Score 3 of abutment: voids/bubbles of a size between 500 μm and 2 mm are seen within the abutment. (e) Score 4: voids/bubbles larger than 2 mm are evident.

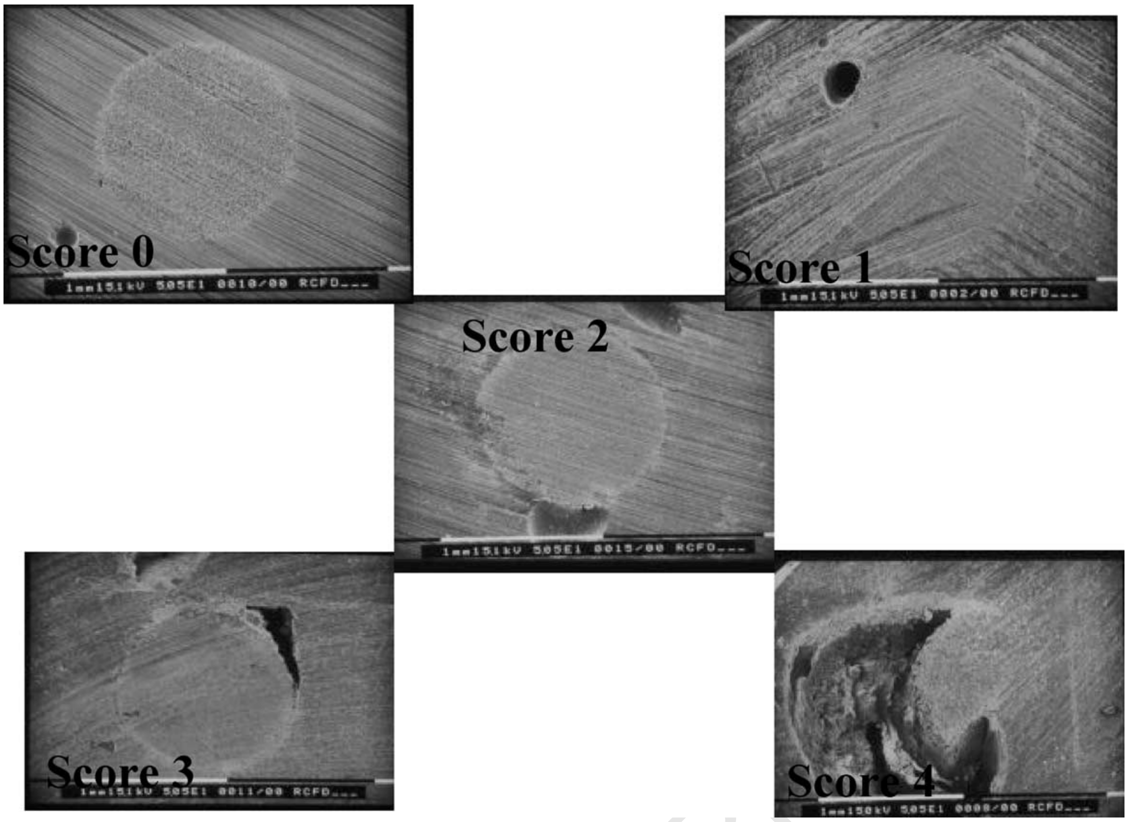

Figure 2 Scores at the adhesive interface. (a) Score 0: no gap is detectable. (b) Score 1: a gap no longer than 200 μm is visible at the interface. (c) Score 2: a gap between 200 and 500 μm long is evident. (d) Score 3: a gap extending for 500 μm–1 mm along the interface is detected. (e) Score 4: the gap along the interface extends longer than 1 mm.

Statistical analysis

The Kruskal Wallis Non Parametric Analysis of Variance was applied to test the significance of the differences among all of the tested groups. The Mann–Whitney U test was used for post hoc comparisons. The Mann–Whitney U test was also applied to verify the significance of the differences between the results yielded by one same material used with and without shells (comparison between Groups 1 and 5, Groups 2 and 6, Groups 3 and 7, Groups 4 and 8). For all the statistical tests the level of significance was set at $p < 0.05$.

Results

Among the four materials used without shells, Gradia (Group 3) showed the least presence of voids/bubbles within the resin abutments. The difference was statistically significant (Fig. 3a). When the scores at the interface were compared among the same four materials, Z100 (Group1) gave proof of a significantly better adaptation on the post than the other three materials (Fig. 3b).

When plastic shells were used, the specimens of Group 8 (Build-it!) yielded the best result, showing a very good structural integrity of the abutments, and a continuous adaptation of the core material around the post (Fig. 4a and b). Also Gradia (Group 7) performed significantly better than Lumiglass (Group 6) as far as the continuity of the material around the post was concerned (Fig. 4b).

The comparison between the results given by each composite used with and without shells revealed that Z100, Lumiglass, and Gradia yielded a better core homogeneity and a more satisfactory adaptation around the post when they were used without shells. With Build-it! similar results in terms of core integrity were achieved either with or without a shell, whereas the presence of the matrix significantly improved the adaptation of the material around the post.

Discussion

Among the several studies over the past 10 years that have been evaluated in vitro[6,7,15,17–21] and in

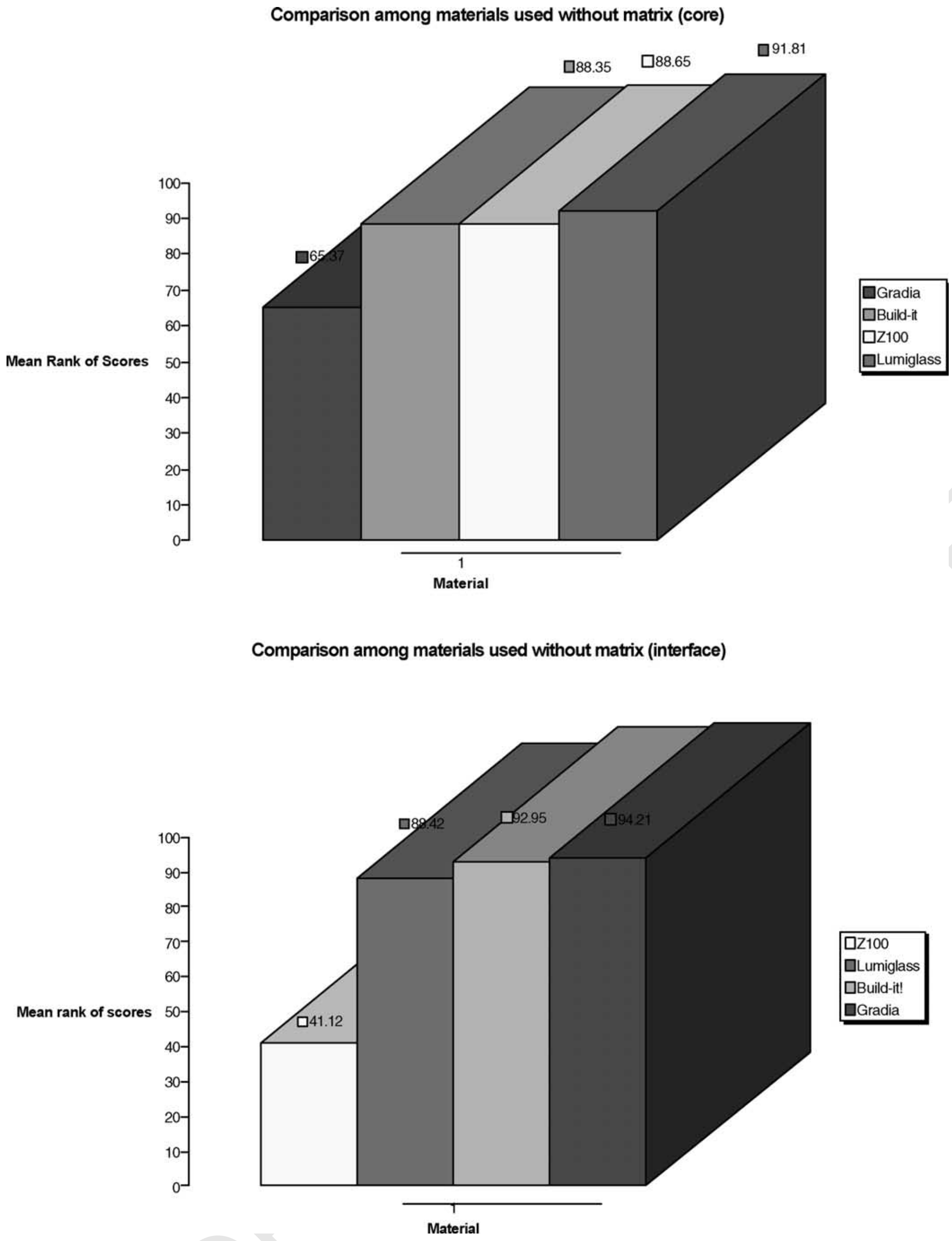

Figure 3 Comparison among the scores recorded for the four materials, tested without the use of a plastic shell. The *y* axis of the graphs indicate the mean rank that was assigned to each material through the statistical elaboration of the ordinal data. The materials that yielded statistically similar results have their columns underlined by the same segment. (a) Evaluation of the core integrity. (b) Assessment of the integration between core material and fiber post.

vivo[9-11,14] the performance of fiber posts, none has so far focused on the homogeneity of the resin abutment, and on the continuity of the bonding interface between the post and the core material. These structural characteristics of the fiber post–resin core unit can play an important role on the longevity of the final restoration of the endodontically treated tooth.

The presence of voids/bubbles within the resin cores and the development of gaps along the interface with the post, negatively affects the strength of the abutment, thus increasing the risk of its fracture under functional loading.[13]

The occurrence of limited ditching of the core portion is usually overlooked in clinical reports, as it is considered unlikely to result in clinical failure of

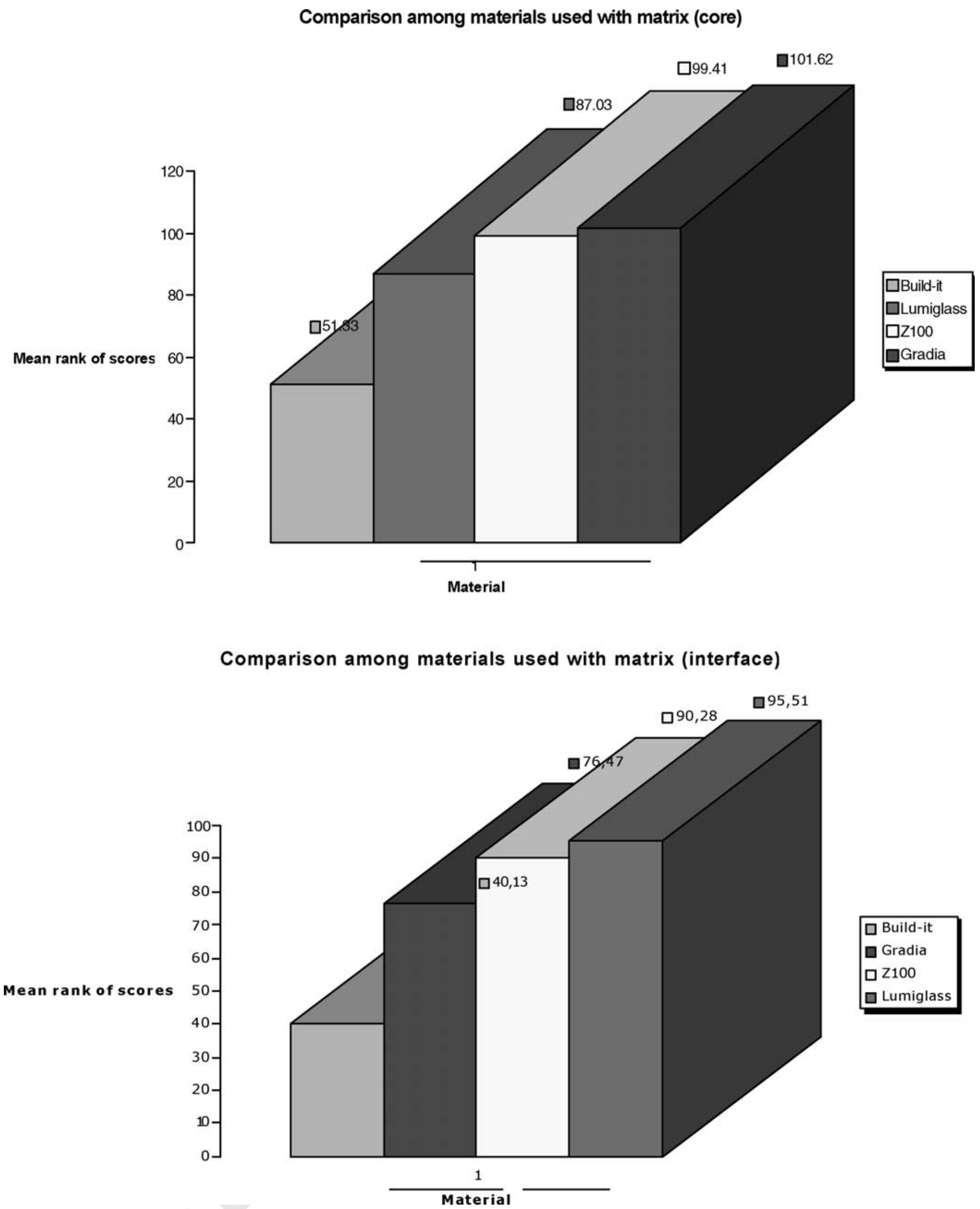

Figure 4 Comparison among the scores recorded for the four materials, tested with the use of a plastic shell. The *y* axis of the graphs indicate the mean rank that was assigned to each material through the statistical elaboration of the ordinal data. The materials that yielded statistically similar results have their columns underlined by the same segment. (a) Evaluation of the core integrity. (b) Assessment of the integration between core material and fiber post.

the restoration. However, the detachment of small fragments of material from the core can alter the shape or the profile of the abutment, thus lowering the retention of the crown.

Even in the case where the fracture has taken off the most part or total of the core portion, the event still does not have to be considered as irreversible failure of the restoration, since the abutment can be re-built. However, the procedure would be time-consuming, and possibly also involving the replacement of the post.

In order to strengthen the post-and-core unit, it seems advisable that the coronal end of the post be surrounded by the core material for at least 1 mm of length. In order to achieve this proper integration between post and core, the step of cutting the end of the post-protruding from the root becomes a critical step.[22]

Different types of composite resins currently on the market could be used to build up a core onto a fiber post. Relatively stiff self-curing resins would have the advantage of providing a stable support to the crown on top. On the other hand, more elastic composites, such as flowable and light-activated materials, tend to have an easier handling and a better integration with the fiber post surface, thus leaving little room for bubbles/voids within the abutment, and for discontinuities along the core-post interface. In addition, it is easy to prepare these materials with diamond burs for crown adaptation.

Self-curing resin should in any case be preferred in the presence of a plastic shell. Although transparent shells are claimed to let the light pass through, the results of the present study seem to point out that the light-curing process of the core material can be negatively affected by the interposition of the plastic matrix. That would explain the finding of a more frequent occurrence of voids/bubbles within the abutments and of interfacial gaps along the post-surface, when the core was built up in the presence of a shell. In this investigation, Build-it!, a reinforced resin composite, was the only material to yield better results when used in combination with shells. As a matter of fact Build-it! is, among the tested materials, the only specifically conceived for core build-ups in combination with shells, whereas the other three materials on trial are most commonly used for direct restorations.

Microscopic investigations usually provide a qualitative appraisal of the characteristics of a material or an interface.[23] In the present study, an original method was proposed to quantify through an ordinal scale the integrity within the resin abutment and the adaptation of the core material onto the post surface. The expression of qualitative aspects through an ordinal scale allows for the application of relatively more elaborate and powerful statistical analysis. In addition, once an index is defined, it can also be applied in subsequent studies and, with reference to it, it becomes possible to compare different materials or to evaluate new products. The use of predefinite scores has recently been proposed for assessing the quality of endodontic and restorative procedures.[24,25]

The Aesthetic Post Plus type of fiber post (RTD, St Egeve, France) was chosen as being one of the most popular on the market, and because several clinical trials have already been conducted on it.[13,14,26] Many types of prefabricated post are currently available to the clinician, from the carbon and quartz posts, to the wide variety of glass fiber and resin matrix posts. The various categories of posts differ in chemical composition, physical properties, and handling. It would be of interest to carry out an investigation with the same purpose as the present study on the different varieties of posts available.

In this trial the post surface was only coated with a silane agent. It can be expected that other types of post surface treatments, such as sandblasting and/or coating with an adhesive material, would be able to enhance the integration between post and core material.

For a deeper more complete understanding of the properties of resin composites that can be used to build up a core, the microscopic data should be complemented by the results of microtensile bond strength tests, and ideally by the findings of in vivo tests.

The results of this study rejected the null hypothesis tested: type of restorative materials and techniques determine significant morphological differences.

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