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Evaluation of the fracture resistance of all-ceramic zirconia posts by 3 different methods

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Statement of the problem. All-ceramic post-and-core restorations offer a number of advantages compared with systems that use metal build-ups. In certain clinical cases, however, fractures at the joint between the post and core build-up have been reported.
Purpose. The objective, therefore, is to improve the joint between the post and the core build-up.
Material and methods. Three different methods were used to prepare all-ceramic post-and-core restorations; pressing IPS Empress core build-ups to CosmoPost zirconia posts, cementing IPS Empress core build-ups to CosmoPost zirconia posts and Celay-milling of zirconia blanks. A series of ten restorations was prepared for each of the three methods. The post-and-core complexes were tested to failure with the load applied perpendicular to the post axis. The load and deflection at fracture were recorded.
Results. The highest breaking load and highest deflection were recorded for the cementing technique with values of 25.3 N and 394 ㎛, respectively. The corresponding values for the pressed core build-ups and the milled zirconia core build-ups were 22 N and 301 ㎛, and 13 N and 160 ㎛, respectively. All the differences are statistically significant ($p=0.05$). Regarding the load-dependence of the deflection, the cemented core build-ups again demonstrated the highest value with 15.5 ㎛/N. The difference in the values of 13.6 ㎛/N and 13 ㎛/N recorded for the pressed-on and milled core build-ups, respectively, were statistically insignificant.
Conclusion. In regard to the high fracture resistance of zirconia post, adhesive cementing the core build-up to the post offers a viable alternative to the conventional pressing technique. The elastic bond between the rigid high-strength zirconia post and the core build-up presents an additional advantage.

Key Words :
Zirconia post, IPS Empress, CosmoPost, Celay/copy-milled, core build-up, fracture resistance

All-ceramic post and core restorations offer distinct advantages with regard to tissue compatibility and aesthetic appearance compared with cast core build-ups.[1-5] Zirconium oxide, or zirconia as it is also called, offers optimal mechanical strength and fracture toughness.[6-8] High fracture resistances, therefore, can be expected of industrially prefabricated zirconia posts.[8-11] Nevertheless, cracking of the post at the joint with the core build-up has been reported in clinical situations.[12]

The core build-up usually consists of a ceramic material that matches that of the post. It is pressed to the zirconia post using the lost wax technique.[13-14] The question is whether or not the stresses generated between the post and the core build-up negatively influence the fracture strength of the post. A possible alternative to this method would be hot-pressing the core build-up separately and the cementing it to the post.[15] Another possibility would be to fabricate the entire post and core complex from presintered zirconia blanks using copy-milling[8,16,17] or CAD/CAM techniques.[18-20]

The present study evaluates whether or not the fracture resistance of the post in such post and core restorations can be improved by using the latter methods rather than the technique of pressing the core build-up to the post.

MATERIAL AND METHODS

In order to facilitate the mounting of the samples for the fracture tests and ensure good reproducibility during the fabrication procedure, a rotationally symmetrical cylinder geometry was chosen for the core build-ups and a simple idealized inlay was used at the transition to the post (Fig. 1).

The size of the core build-up corresponded to that of a restoration for the anterior dentition.

Fabrication of test specimens

Two of the test series conducted combined CosmoPost zirconia posts (Ivoclar, Schaan, Liechtenstein) with Cosmo pressing ceramic (Ivoclar, Schaan, Liechtenstein)(Table Ⅰ). In the third test series, the entire post-and-core complex was fabricated with the Celay technique using zirconia blanks (Vita, Bad Säckingen, Germany). Ten test specimens were fabricated for each series (Fig. 2).

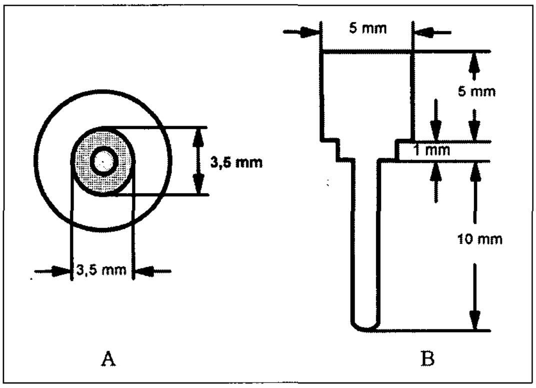

Fig. 1. Schematic diagram of the geometry and dimensions of the core build-ups(a, core build-up; b, core build-up with post).

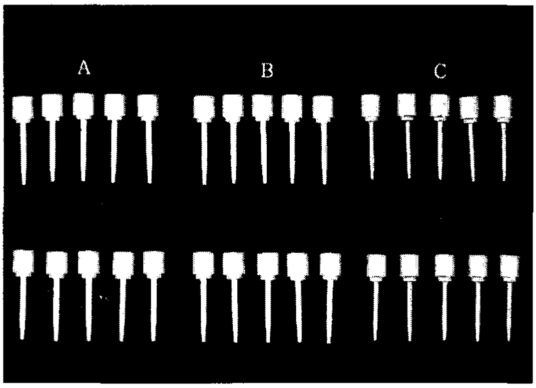

Fig. 2. Zirconia Post Specimens with core build-up. A, pressed-on core build-up; B, cemented core build-up; C, Celay zirconia core build-up.

1) CosmoPost with pressed core build-up

Cylindrical build-ups with the dimensions shown in Figure 1 were fabricated from 5-mm diameter acrylic rods. These were bonded to the CosmoPost zirconia posts using cyanoacrylate such that the end surfaces of the post and the core build-up were flush (Fig. 1). The patterns were invested in accordance with the IPS Empress method following the instructions of the manufacturer (Table Ⅰ). After preheating to 850 ℃, Cosmo Type 2 pressing ceramic was pressed to the post at 900 ℃. The post and core assemblies were divested and jet-cleaned with corundum (Al_2O_3, 50 ㎛) at 1 bar.

2) CosmoPost with cemented core build-up

Cylindrical acrylic core build-ups (Fig. 1) were invested and the build-ups pressed using the CosmoPost ingots in conjunction with the IPS Empress method. After divesting, the surfaces and hole of each build-up were jet-cleaned with 50 ㎛ corundum at 1 bar. The surface of the hole was etched with hydrofluoric acid ceramic etching gel (Ivoclar, Schaan, Liechtenstein) for one minute. After rinsing off the etching gel and drying, the restorations were silaned with Monobond S (Ivoclar) and coated with Heliobond (Ivoclar). The contact surfaces of the posts were jet-cleaned with corundum and silaned. The contact surfaces of the post as well as the walls of the hole were lightly coated with Panavia 21 (Kuraray, Osaka, Japan). Finally, the post was inserted into the core build-up using slight rotating movements.

3) Copy milling of post-and-core assemblies made of zirconia blanks

Zirconia blanks for posterior teeth (Table Ⅰ) were cut lengthwise into four pieces using a water-cooled diamond saw. Post-and-core assemblies were machined from these pieces using the Celay copy milling technique. An acrylic core build-up such as the one used in the first series served as the milling pattern (Fig. 1). Following a firing cycle to remove any moisture, the milled ingots were infiltrated with Z 22 zirconia glass powder according to the In-Ceram procedure. After removing excess glass, the post-and-core assemblies were jet-cleaned with 50 ㎛ corundum at 6 bar and fired to ensure that all the pores had been infiltrated with glass.

Measurements

1) Post diameter

Prior to fracture testing of the completed test pieces, the diameter of the post was measured at

Table Ⅰ. Procedures and materials for the fabrication of the post and core assemblies in series 1 to 3

	Series 1	Series 2	Series 3
Post	CosmoPost ZrO2	CosmoPost ZrO2	ZB 33 zirconia blanks
Core	Cosmo Type 2, Class 1	Cosmo Type 2, Class 1	ZB 33 zirconia blanks
Procedures	IPS Empress / hot-pressing	IPS Empress / hot-pressing post/core cement	Celay / copy-miling glass-infiltration zirconia glass power
Company	Ivoclar, Schaan, Liechtenstein	Ivoclar, Schaan, Liechtenstein	Vita, Bad Sackingen Germary

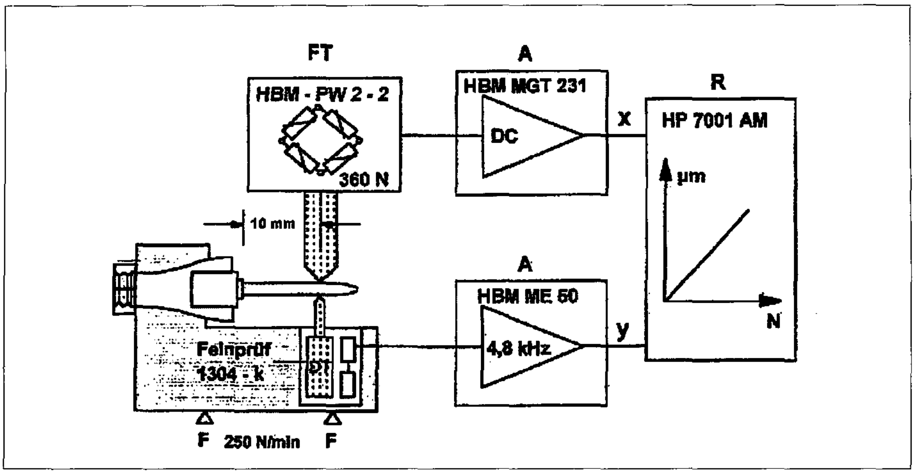

Fig. 3. Diagram of the measurement set-up(FT, Force Transducer; A, Ampifier; R, x-y Recorder; DT, Inductive Displacement Transducer; F, Force; HBM, Hottinger Baldwin Messtechnik (Stuttgart, Germany); Feinprüf (Göttingen, Germany); HP, Hewlett-Packard(San Diego, USA).

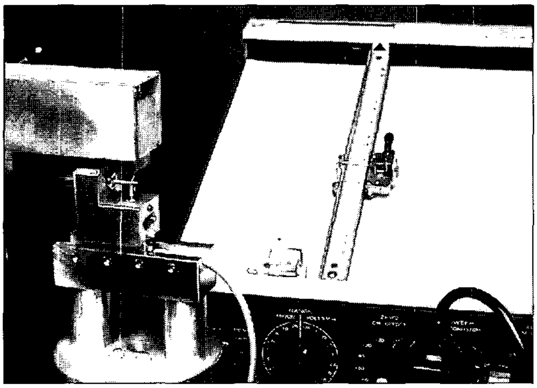

Fig. 4. Force transducer with a feinprüf machine and x-y recorder.

the post-buildup joint with 10 µm resolution using electronic sliding calipers (Mitutoyo, Type CD-15D, Japan).

2) Strength measurements

The breaking load and the deflection of the posts at the point of load application were measured.

The test pieces were secured with the post axis horizontal in a pneumatic testing apparatus using a split chuck to grip the cylindrical build-up (Fig. 3).

The load, at a load rate of 250 N/min, was applied vertically to the post axis at a distance of 10 mm from the build-up. Deflection was measured with an inductive displacement sensor. The force and deflection values were recorded as x-y plots (Fig. 4).

Statistical procedure

The statistical evaluation of the measuring values was conducted with the Statgraphics Plus Version 7 program (cumulative statistics, multiple box plots, variance analyses, multiple comparisons according to Bonferroni).

RESULTS

1) Post diameter

The CosmoPosts in the first and second series demonstrated a similar average diameter of 1.376 and 1.384mm, respectively. The difference between the maximum and minimum value was 40 µm. (Table Ⅱ) The standard deviation was 11 µm in the first series and 12 µm in the second series. Deviations from rotational symmetry in the milled zirconia posts resulted in an average diameter of 1.3 mm with a standard deviation of 26 μm and a maximum measured difference of 80 μm.

2) Crack propagation

Cracks propagated differently in the three test series. In the first series in which pressed core build-ups were tested, the posts always fractured at the post build-up joint (Fig. 5). The cemented post-and-core restorations always fractured within the build-up, resulting in spalling of the inlay or cracking of the build-up (Fig. 6). Because of the method used to fabricate the zirconia posts of the third test series, these restorations possessed a small radius of curvature at the joint of the post and the core build-up. Consequently, the fracture occurred within the post below the core build-up (Fig. 7).

Table Ⅱ. Post diameter in mm

	Mean	SD	Min	Max
Series 1	1.38	0.011	1.35	1.39
Series 2	1.38	0.012	1.36	1.40
Series 3	1.29	0.026	1.255	1.33

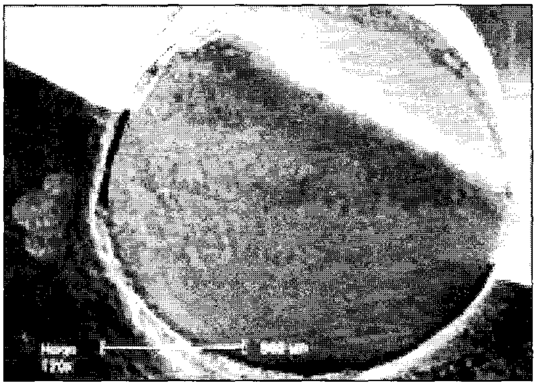

Fig. 6. Fracture surface of a CosmoPost with a cemented core build-up(×120).

3) Breaking load and deflection

The scattering of the measuring values was high in the first and second series in particular (Fig. 8). The relative standard of deviation, however, was of the same order for all the series with 15~16 % of the average value. The highest average breaking load of 25.3 N was recorded for the second series in which the posts were cemented to the core build-ups (Table Ⅲ). The posts with pressed core build-ups followed with 22 N and the milled restorations with 13 N. The differences between the series are statistically significant (p=0.05).

The maximum deflection of the posts at failure

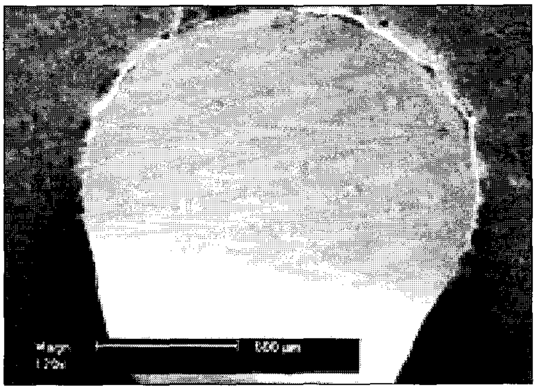

Fig. 5. Fracture surface of a CosmoPost with a pressed-on core build-up(x120).

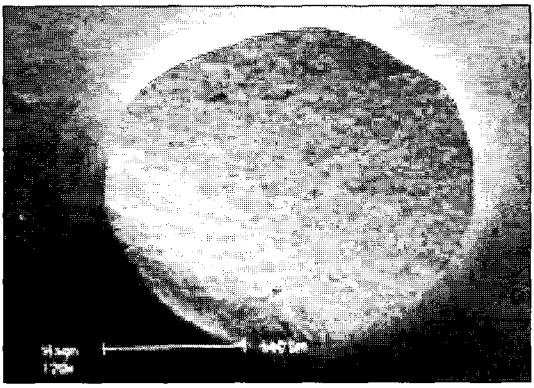

Fig. 7. Fracture surface of a post with a core build-up fabricated using the Celay procedure and zirconia blanks(×120).

Table Ⅲ. Breaking load of the posts in N

	Mean	SD	Min	Max
Series 1	22.0	3.6	16.3	26.5
Series 2	25.3	4.2	16.3	32.5
Series 3	13.0	1.9	10.0	16.0

Table Ⅳ. Post deflection at breaking load in ㎛

	Mean	SD	Min	Max
Series 1	301	71.0	180	408
Series 2	394	90.8	248	520
Series 3	160	22.3	125	188

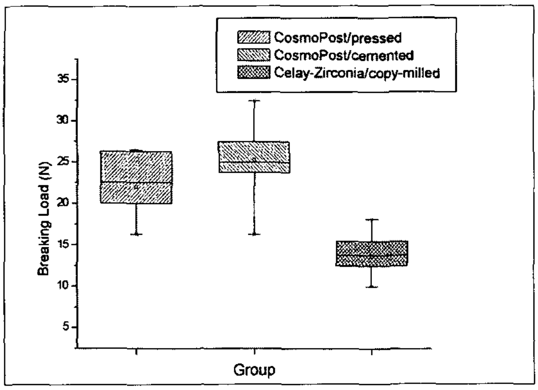

Fig. 8. Box plot diagram of the post breaking loads(1, pressed-on core build-up; 2, cemented core build-up; 3, Celay zirconia core build-up).

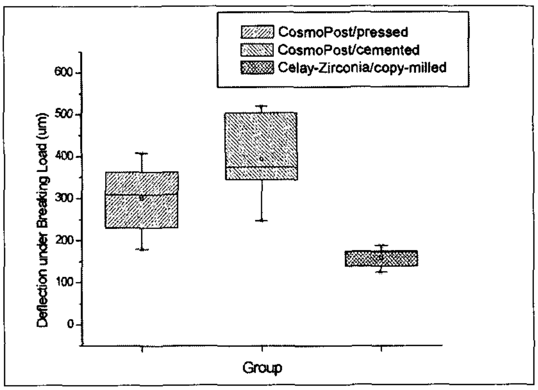

Fig. 9. Box plot diagram of the deflection of the posts under breaking load(1, pressed-on core build-up; 2, cemented core build-up; 3, Celay zirconia core build-up).

Table Ⅴ. Angular Coefficient between Deflection and Load of the post in ㎛/N

	Mean	SD	Min	Max
Series 1	13.5	2.3	11.0	18.9
Series 2	15.5	1.7	13.8	18.6
Series 3	12.9	1.6	10.2	15.0

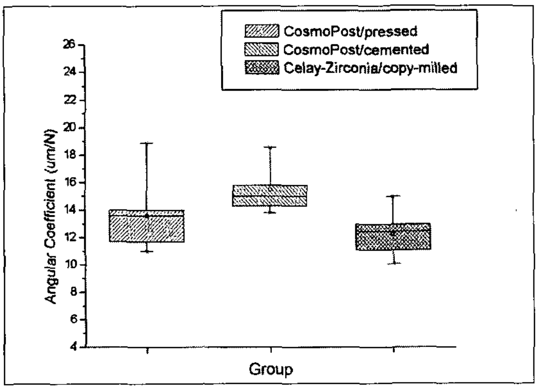

Fig. 10. Box plot diagram of the angular coefficient between deflection and breaking load of posts(1, pressed-on core build-up; 2, cemented core build-up; 3, Celay zirconia core build-up).

produced similarly high fluctuations in the measuring values and the same sequence of the series (Fig. 9). The highest average value of 394 ㎛ was recorded for the cemented core build-ups. The posts with pressed core build-ups followed with 301 ㎛ and the milled restorations with 160 ㎛ (Table Ⅳ).

All the differences are statistically significant (p= 0.05).

The slope of the x-y plots, i.e the load-dependency of the post deflection, was highest for the cemented core build-ups at 15.5 ㎛/N (Table Ⅴ). The pressed core build-up series and the monolithic zirconia series both exhibited similar values with 13.5 ㎛/N and 12.9 ㎛/N, respectively (Fig. 10, 11). The latter two series did not differ from each other (p=0.05). The second series, however, greatly differed from the first and the third series (p= 0.05).

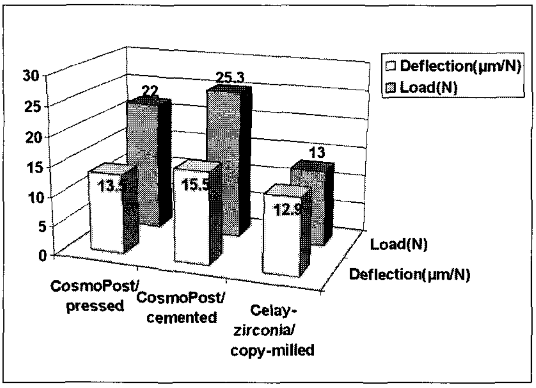

Fig. 11. Evaluation of the fracture resistance of all-ceramic zirconia posts by 3 different methods.

DISCUSSION

A comparison of the results shows that the three series demonstrated clear differences for all the parameters. For the pressed build-up, the crack propagation path shows that because of the rigid joint between the core build-up and the post, the maximum stress level during the bending test is located at the post-build-up joint. Because of the elastic composite intermediate layer in cemented post-and-core complexes, the area over which the maximum stress is exerted is larger. Consequently, these posts failed under loads that were 15 % higher. The higher breaking loads in this case must also be attributed to the fact that the posts are less rigidly held in place.

The lower breaking load values as well as the crack propagation characteristics in the milled zirconia restorations are related to the fabrication procedure. Larger deviations in the dimensions are to be expected in the copy-milling technique compared with industrial fabrication procedures. In addition, the surfaces must be reground after glass infiltration. As a result, the average post diameter is reduced by 80 μm and the standard deviation of 26 μm is 120 % higher than in industrial fabrication procedures. However, the 40 % lower fracture resistance compared with CosmoPosts with pressed core build-ups cannot be explained by the fluctuations in the diameter alone. Inhomogeneities and superficial microcracks, which are unavoidable during manual working procedures such as glass infiltration, must also be taken into account.

The milled zirconia restorations and the CosmoPosts with the pressed core build-ups, however, did not demonstrate any differences in load dependence of the measured post deflection. Since the two materials possess very similar materials properties and the posts were rigidly fixed in both cases, there is no inconsistency with regard to the other observed data. Greater deflections for a given load are to be expected with the cemented specimens because the post is less rigidly fixed.

Given the high breaking loads, cementing the core build-up to the post offers a viable alternative to the conventional pressing technique. The elastic bond between the rigid high-strength zirconia post and the core build-up presents an additional advantage. In functional masticatory situations, the load peaks are smaller compared with those of restorations that are rigidly fixed, at least if an off-axis load is applied. Results of the long-term clinical effectiveness of this method using zirconia posts are not yet available.

CONCLUSION

In regard to the high fracture resistance of zirconia post, adhesive cementing the core build-up to the post offers a viable alternative to the conventional pressing technique. The elastic bond between the rigid high-strength zirconia post and the core build-up presents an additional advantage.

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