JOURNAL OF ENDODONTICS
Printed in U.S.A.
VOL. 28, NO. 10, OCTOBER 2002

Survival Rate and Fracture Strength of Incisors Restored with Different Post and Core Systems and Endodontically Treated Incisors without Coronoradicular Reinforcement

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This in vitro study evaluated the survival rate and fracture resistance of maxillary central incisors restored with different post and core systems. The post and core systems investigated were a prefabricated high precious metal post with cast core (group A), zirconia post with a prefabricated bonded ceramic core (group B), and a resin-ceramic interpenetrating phase composite post (experimental) with a prefabricated bonded ceramic core (group C). The all-ceramic copings were cemented using Panavia 21 TC. In the group without coronoradicular reinforcement, the access cavity was closed with a light-cured composite in combination with a dentine-bonding agent (group D). Each specimen was intermittently loaded and thermocycled before final stress tests in a Zwick machine. The survival rates after 1,200,000 cycles in the artificial mouth were 90% (group A), 80% (group B), 60% (group C), and 100% (group D). Statistically significant differences were found between all groups with the exception of A and B, when failure during cyclic loading was included (Kruskal-Wallis multiple comparisons test). Samples restored with a cast post and core demonstrated more vertical root fractures. It was concluded that the preservation of both internal and external tooth structure is of utmost importance when restoring endodontically treated teeth.

Posts were recommended over 100 yr ago when restoring teeth with artificial crowns (1). The role of moisture loss (2), the nature of dentin (3), alterations in strength caused by architectural changes in the morphology of teeth (4), concepts of biomechanical behavior of tooth structure under stress (4), and changes in the collagen alignment (5) are considerations when restoring endodontically treated teeth.

Clinical retrospective studies have shown that posts do not strengthen teeth, and post and core restorations may result in root fractures or perforations, post fractures, and post dislodgement (6, 7). Due to substantial loss of coronal tooth structure, coronoradicular stabilization is often required, especially in anterior teeth to provide retention and resistance form for the restoration. Ideal posts should impart minimal stress to the tooth, provide adequate retention to the core, and be easily removed to permit endodontic retreatment. Mechanical testing methods have demonstrated the biomechanical advantages of adhesive posts and cores (8).

Because of the increasing demand from patients and clinicians for esthetic replications of the natural dentition, researchers and dental manufacturers have explored the potential of developing metal-free all-ceramic restorations (9). The esthetic result of all-ceramic restorations is influenced by several factors, such as post-core materials, luting cement color, and shade (10). Because light transmission is impeded by metallic posts, the use of tooth colored post and core systems is advocated to allow light transmission through the post structure (11). Recently, white posts made of zirconium dioxide, partially stabilized by the addition of yttrium oxide (12), carbon fiber (13), and quartz fiber (14), were introduced in dentistry.

Fatigue tests have been established as an essential research tool for testing adhesive restorations, because they reproduce a cyclic loading pattern comparable to physiologic function and can, therefore, simulate the results of time-consuming clinical trials. More recently, such tests have been applied to posts and cores (13).

The aim of this investigation was to compare the survival rate and fracture strength of endodontically treated maxillary central incisors restored by three different post and core systems covered with all-ceramic copings with endodontically treated maxillary central incisors without coronoradicular reinforcement after exposure in an artificial mouth.

MATERIALS AND METHODS

Forty, freshly extracted, maxillary central incisors were used in the study. The root canal systems were cleaned, shaped, and obturated three dimensionally with vertically compacted, warm gutta-percha and sealer. The teeth were randomly assigned to 4

TABLE 1. Experimental groups and post systems under investigation

Group	Treatment	Post Size ISO
A	Cast post and core in combination with a PROCERA crown	90
B	Zirconia post in combination with a PROCERA crown	90
C	Resin-ceramic interpenetrating phase composite post in combination with a PROCERA crown	90
D	Access cavity closed with a light-cured composite	

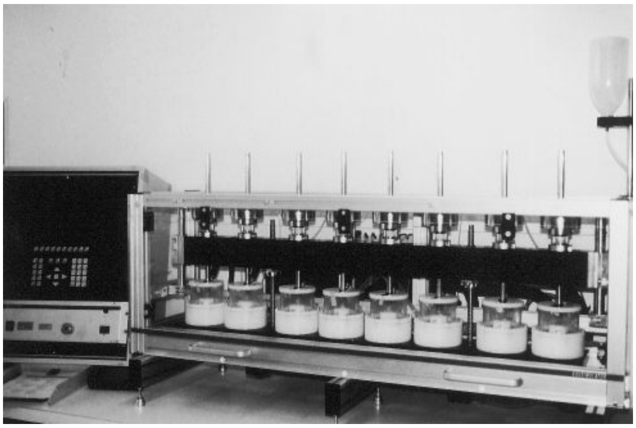

FIG 1. Artificial oral environment (Willytech).

groups, each containing 10 samples (Table 1). The crown of each tooth in groups A, B, and C was removed 2-mm coronal to the CEJ and perpendicular to the long axis of the tooth. The root canals were then sequentially enlarged and trimmed with a series of specific cylindrical burs, according to the manufacturer's directions (ER-Postsystem, Size 2, Brasseler, Lemgo, Germany). Post preparations were made 5-mm short of the apex.

In group A, prefabricated posts of high precious alloy (Permador, ISO 90, Brasseler) were fitted in the canals. Direct build-ups were then made for the fabrication of the patterns for the cores (Duralay, Reliance Dental Manufacturing, Worth, IL), using a silicone key. The patterns were vacuum invested (Ceramigold, Whip Mix, Louisville, KY) and cast (CLG-77, Heraeus, Germany) with a high noble gold alloy (Olympia, J.F. Jelenko & Co., Armonak, NY). The prefabricated posts with cast cores were sandblasted with aluminum oxide (50 μm at 2.5 bar) and cemented with Fleck's zinc phosphate cement (Mizzy, Cherry Hill, NJ).

In group B, prefabricated zirconia posts (Cerapost, ISO 90, Brasseler) were fitted in the canals. The posts were then sandblasted with aluminum oxide (50 μm at 2.5 bar) and cleaned with chloroform. The dentin was etched with 37% orthophosphoric acid for 10 s, rinsed with water for 60 s, and finally, rinsed with alcohol. A prepared dentin-bonding system (Scotchbond Multi-Purpose Dental Adhesive, 3M, Irvine, CA) was then applied, and the posts were cemented with a chemically cured translucent composite cement (Panavia 21 TC, Kuraray, Osaka, Japan). The core buildups were completed with prefabricated glass ceramic caps (Ceracap F1, Brasseler) cemented with a light-cured composite in combination with a dentine-bonding agent (Herculite, Kerr, Romulus, MI).

In group C, resin-ceramic interpenetrating phase composite posts (RCIPC) were used as the posts. The material, which is under development, was a resin-ceramic matrix composite that involved the resin infusion of a porous aluminous-based ceramic matrix. Posts were milled by using the Celay copy milling machine (Microna, Spreitenbach, Switzerland), exactly replicating the dimensions of the posts used in groups A and B. The posts were cemented with a chemically cured translucent composite cement (Panavia 21 TC, Kuraray). The pretreatment of the dentin and the insertion of the prefabricated glass ceramic caps (Ceracap F1, Brasseler) were the same as in group B.

TABLE 2. Fractures in the artificial oral environment

Group	Fractures	No. of Cycles	Location
A	1	1,100,000	Coping
B	2	122,100	Coping
		481,514	Coping
C	4	117,881	Coping and post and core
		208,410	Coping and post and core
		208,410	Coping and post and core
		125,820	Coping and post and core
D	0	—	—

TABLE 3. Fracture resistance (N) during static loading

Group	Mean	SD
A	1270	312.5
B	1494.5	333.5
C	1146.7	182.6
D	2362.5	673.1

In group D, the access cavities were closed with a light-cured composite in combination with a dentine-bonding agent (Herculite, Kerr). The samples in this group didn't have any coronoradicular reinforcement, and thus, the root canals were not prepared for a post space.

Hydrocolloid impressions (Super Body 500, Super Syringe 252, Gingi-Pak, Belport, Camarillo, CA) were taken of the 30 samples in groups A, B, and C, and master dies were poured (Fuji-Rock, GC, Tokyo, Japan). All-ceramic copings with a thickness of 0.6 mm were then fabricated by using the Procera-system (Nobel Biocare, Stockholm, Sweden). The all-ceramic copings were cemented using Panavia 21 TC (Kuraray), and each sample was embedded in a self-curing polyester resin (Technovit 4000, Kulzer, Wehrheim, Germany) within the sample holder of the artificial oral environment (Fig. 1). Following the concept of biologic width, the distance from the coping margin to the polyester resin was 3 mm. All samples were exposed to a 5-yr simulation in the artificial environment (Willytech, Munich, Germany). The survival rates of the four groups were then calculated using the Kaplan-Meier analysis, after which each specimen was loaded in the Zwick universal testing machine (Zwick, Neuulm, Germany) until fracture. The controlled loads were applied to the crowns 2-mm below the incisal edge on the palatal side at a 135-degree angle to the long axis of the root. The testing machine was set at a crosshead speed of 0.5 mm/min at a load cell capacity of 100 kg. Load magnitude was recorded by the Zwick testing machine, and failure threshold was defined as the point at which a sample could no longer withstand increasing load and fracture of the coping, post and core, or root occurred. Mode of failure was also recorded and photographs were

TABLE 4. Statistical analysis of the influence of different build-ups on the failure loads of endodontically treated maxillary incisors in a Zwick testing machine (Kruskal-Wallis test)

		Mean			Mean			Mean			Mean			
grp	N	Score	grp	N	Score	grp	N	Score	grp	N	Score	Df	Chi-square	Tail Probability
A	10	12.8	B	10	18.45	C	6	8.92	D	10	30	3	19.818	0.0002***

TABLE 5. Statistical analysis of the influence of different build-ups on the failure loads of endodontically treated maxillary incisors in a Zwick testing machine (Kruskal-Wallis multiple comparisons corrected statistic of pairwise comparisons)

Class Number	GRP	Frequency
1	A	10
2	B	10
3	C	6
4	D	10

Categories of Classes	Cumulative Chi-square	df	Local Tail Probability	Maximum on Path to Top	
1–2	2.4032	1	0.1211	0.1211	ns
1–3	1.2990	1	0.2544	0.2544	ns
2–3	3.4100	1	0.0648	0.0936	ns
1–4	12.6229	1	0.0004	0.0004	***
2–4	8.2514	1	0.0041	0.0084	**
3–4	10.5882	1	0.0011	0.0015	**

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns = not significant.

TABLE 6. Statistical analysis of the influence of different build-ups on failure loads of endodontically treated maxillary incisors in a Zwick testing machine, including the number of cycles in the oral artificial environment (Kruskal-Wallis test)

		Mean			Mean			Mean			Mean			
Grp	N	Score	grp	N	Score	grp	N	Score	grp	N	Score	Df	Chi-square	Tail Probability
A	10	16.8	B	10	22.45	C	10	8.75	D	10	34	3	24.731	0.0000***

TABLE 7. Statistical analysis of the influence of different build-ups on failure loads of endodontically treated maxillary incisors in a Zwick testing machine, including the number of cycles in the oral artificial environment (closed test procedure based on multiple Kruskal-Wallis tests)

Class Number	GRP	Frequency
1	A	10
2	B	10
3	C	10
4	D	10

Categories of Classes	Cumulative Chi-square	df	Local Tail Probability	Maximum on Path to Top	
1–2	2.4032	1	0.1211	0.1211	ns
1–3	5.3237	1	0.0210	0.0210	*
2–3	7.8405	1	0.0051	0.0058	**
1–4	12.6229	1	0.0004	0.0004	***
2–4	8.2514	1	0.0041	0.0041	**
3–4	14.2965	1	0.0002	0.0002	***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns = not significant.

taken for every test sample. All data were collected and statistically analyzed (Kruskal-Wallis multiple comparisons test).

RESULTS

Seven out of 40 samples fractured partially or totally during dynamic loading in the artificial oral environment (Table 2). The survival rates after 1,200,000 cycles in the artificial oral environment were as follows: 90% group A, 80% group B, 60% group C, and 100% group D. Four samples in group C could not be exposed to static loading, because the copings and the post and cores had fractured during the dynamic loading test. The results of the means and standard deviations of static loading of all groups are shown in Table 3. Statistically significant differences between all groups were found with the exception of groups A and B, groups A and C, and groups B and C (Tables 4 and 5). Tables 6 and 7 give the statistical analysis of the different failure loads between groups when the number of cycles before failure in the artificial oral environment occurred is also included. Specimens in group D demonstrated the best mean score, whereas those in group C showed the worst. Statistically significant differences were found between all groups, except A and B.

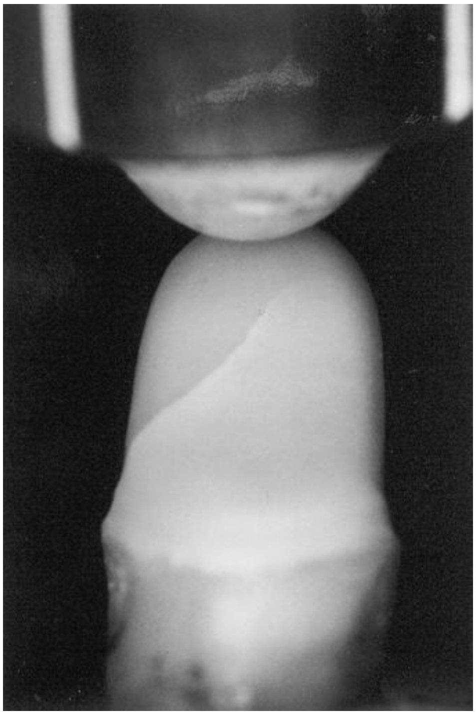

FIG 2. Cracking of a PROCERA coping in the artificial oral environment (group A).

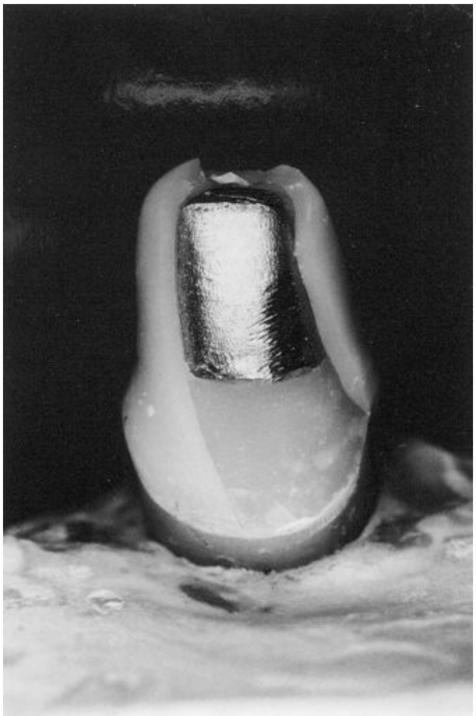

FIG 3. Fracturing of a PROCERA coping in the artificial oral environment (group A).

Microphotographs of the samples revealed different failure modes between the experimental groups. Specimens from group A showed vertical root fractures (Figs. 2, 3, and 4), whereas those in groups C and D fractured horizontally along the CEJ (Figs. 5, 6, and 7). In group B, fracturing of the coping and core build-up, but not the zirconia post or root, occurred (Figs. 8 and 9).

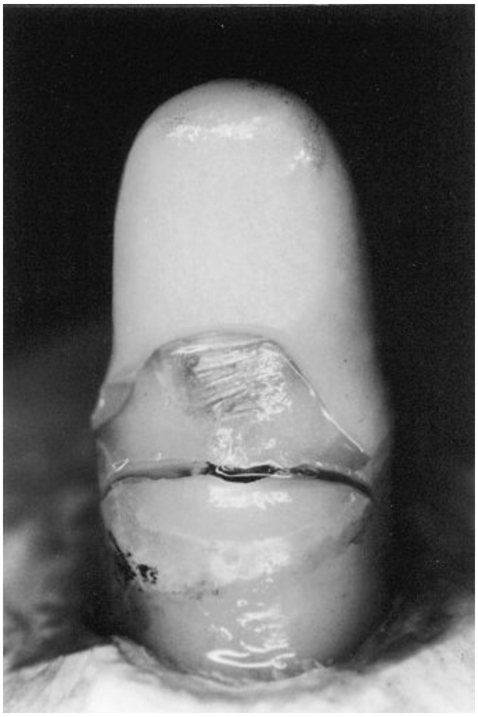

FIG 4. Failure of a specimen in the Zwick testing machine (group A).

FIG 5. Fracturing of the root and RCIPC post in the artificial oral environment (group C).

DISCUSSION

In this study, identical posts with a conical design were used. Although this post design demonstrated inferior results in photoelastic stress studies compared with parallel-sided posts, this effect could be equalized after bonding a PROCERA crown with 2-mm margins on sound tooth structure (15).

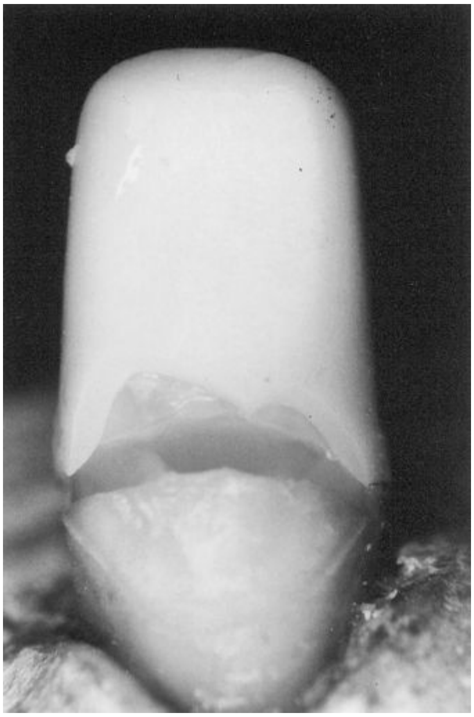

FIG 6. Failure of a specimen in the Zwick testing machine (group C).

FIG 7. Failure of a specimen in the Zwick testing machine (group D).

Endodontically treated maxillary incisors, without any coronoradicular reinforcement, demonstrated significantly higher failure loads than all other groups restored with post and cores and full ceramic crowns. This is in agreement with other studies (6, 7). The results, however, are in contrast to the findings of Kantor and Pines in 1977 (16), which stated that an intraradicular post doubled the fracture resistance of a root. If there is a lot of intact tooth structure remaining, the most conservative approach seems to be the treatment of choice. If a large amount of tooth structure has been removed as the result of endodontic therapy, trauma, decay, and resulting preparation for restorative procedures, the teeth are structurally compromised. Under these circumstances, the build-up with a post and core in combination with a crown becomes necessary.

It has been suggested that a post should have the same modulus of elasticity as root dentin to distribute applied forces evenly along

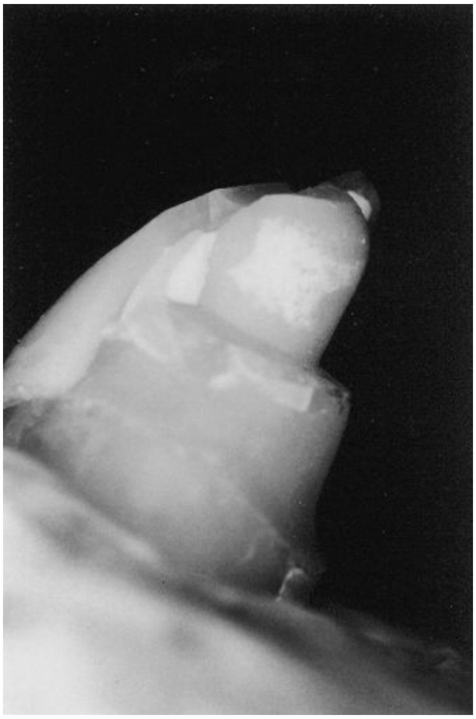

FIG 8. Fracturing of a PROCERA crown and glass-ceramic core in the artificial oral environment (group B).

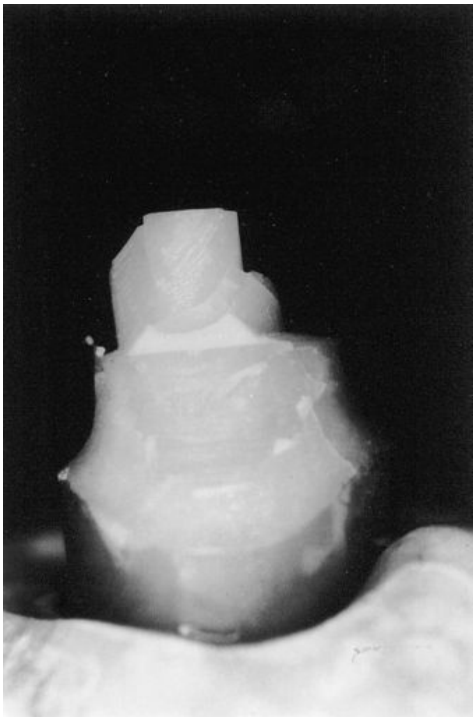

FIG 9. Failure of a specimen in the Zwick testing machine (group B).

the length of the post (13). Although the moduli of elasticity of a post with a cast core and a zirconia post were much higher than that of the experimental RCIPC post, the specimens with the resin-ceramic interpenetrating phase composite posts failed at significantly lower loads than all the other specimens. Apparently RCIPC posts did not fulfill the required mechanical properties. The results of the teeth restored with zirconia posts corresponded to those of other studies (12, 17). Kern et al. (18) followed 80 endodontically treated teeth that were restored with zirconia posts over an average period of 16 months and reported that the survival rate was 100%.

In this study, prefabricated posts with case cores were cemented with zinc phosphate cement, whereas the zirconia and RCIPC posts were bonded by using an adhesive technique. The specimens of the four experimental groups presented different failure modes: teeth restored with prefabricated posts and cast cores mostly revealed complete or incomplete vertical root fractures. This can be explained by some bending of the metallic post when excessive loads were applied resulting in stress fractures of the root. Teeth with zirconia posts demonstrated fractures of the coping and glass ceramic build-up but almost no fracture of the remaining tooth. Apparently, these adhesively bonded zirconia posts were able to reduce the transmission of forces to the root. A recent study favors the use of dentin-bonding agents in combination with composite resins, because they demonstrated that much higher tensile forces were needed to dislodge prefabricated posts when bonding agents were used (19).

The advantages of bonding agents are the absence of wedging effects, less dentin removal because posts can be shorter and thinner, and therefore, lower fracture susceptibility. This may have a very important clinical impact. Teeth restored with RCIPC posts or without any coronoradicular reinforcement fractured completely in the coronal portion in a more or less horizontal way. Comparing the different failure modes, the way teeth with prefabricated posts and cast cores fractured is definitely the least desirable, because those teeth cannot be saved in vivo.

Coronal microleakage seems to be one of the reasons for failure of root canal treatment (20). Because resin cements show lower solubility and adhere to dentin, their routine use in the cementation of posts can be recommended.

Presently, there is no satisfactory procedure for removal of bonded zirconia posts, and before zirconia posts with prefabricated ceramic caps in combination with all-ceramic restorations can be recommended, clinical long-term data should be available.

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