The restoration of endodontically treated, single-rooted teeth with cast or direct posts and cores: A systematic review

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Direct post-and-core restorations with prefabricated posts are becoming increasingly popular. A literature review was conducted to compare the clinical and in vitro performance of cast posts and cores to that of direct cores with prefabricated posts in single-rooted teeth. Research on the restoration of endodontically treated teeth was identified through a search of electronic databases. The search yielded a total of 1773 references. After these references were subjected to strict inclusion criteria, 10 in vitro and 6 in vivo studies remained and critically reviewed. A comparison of fracture loads in the in vitro studies revealed no significant difference between cast and direct posts and cores. Meta-analysis of the data suggested that there is no difference in fracture behavior associated with the 2 treatment modalities. An overall survival analysis was not possible for the in vivo studies. The survival for cast posts and cores in 2 studies ranged from 87.2% to 88.1% and in a third study reached 86.4% for direct cores after 72 months. Randomized clinical trials on this topic were not available but should be conducted to verify published findings. (J Prosthet Dent 2002;87:380-6.)

The dental practitioner is often faced with the task of restoring endodontically treated teeth. Root canal treatment is usually the consequence of caries followed by pulpal infection or traumatic damage to a tooth. Trauma and decay are mostly associated with an extensive loss of tooth structure, necessitating restoration of the tooth with a complete crown for esthetic and functional rehabilitation. When a large portion of the clinical crown has been lost to damage, it often is impossible to achieve sufficient anchorage of a restoration in the remaining dentin. In such situations, a root-canal–retained restoration is required.[1]

In molars, the use of post-retained cores is often unnecessary due to sufficient dentin bulk and axial loading conditions. Because single-rooted teeth (especially incisors) are loaded nonaxially, more stress develops when chewing forces are exerted.[2] Thus, the cast post-and-core procedure has been advocated as the gold standard restoration for decades. Since the introduction of the direct post-and-core restoration,[3] associated techniques and materials have improved significantly.[4] Posts and cores also have been proposed for the stabilization of weakened, endodontically treated teeth. While paradigms are shifting for the restoration of otherwise sound non-vital teeth, alternatives to the cast post and core have not yet enjoyed widespread clinical use.[5,6]

Different approaches can be taken to the fabrication of cast posts and cores. Burn-out plastic patterns or cast-on posts can be fitted to the root canal and then relined with autopolymerizing acrylic. A core pattern can then be built up from autopolymerizing acrylic and subsequently cast in dental alloy. As an alternative, direct restorative procedures are also available. Preformed titanium, stainless steel, or (more recently) carbon-fiber and zirconia posts have been advocated for the buildup of pulpless teeth. The posts are bonded to the tooth, and the actual core is built up from amalgam, cement, or a hybrid composite.[4,7]

While an abundance of in vitro studies on different aspects of post-and-core restorations has been reported in the literature, few studies compare the success of clinically meaningful restorative approaches. Moreover, the materials and materials used vary widely. It is therefore still difficult to justify a preference for cast or direct post-and-core restorations based on in vitro studies alone. In vivo studies are relatively scarce. Creugers et al[8] conducted a systematic review of post-and-core success, but no randomized trials were available for analysis. Moreover, the failure criteria in the reviewed studies were not always clear. The authors did not compare classic cast posts and cores and direct restorative techniques that make use of prefabricated posts and plastic filling material.

A literature review was undertaken to clarify the differences between the 2 restorative options for pulpless teeth that require a complete core restoration. A search of MEDLINE and EMBASE databases was conducted using subject headings combined with appropriate keywords (Fig. 1). The reference lists of retrieved articles published between 1995 and 2000 were screened for additional references. The search was limited to articles in English, French, or German. A total of 1773 publications were identified via this

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search strategy. None were randomized trials of post-and-core restorations.

The retrieved literature was culled with specific inclusion criteria applied by the authors. In vitro studies had to include the following: single-rooted teeth, no resin teeth analogues, complete-crown restorations, and a load angle of 130 to 135 degrees. In vivo studies had to include a follow-up period of ≥3 years; anterior teeth that could be identified separately; complete-crown restorations, including FPD abutments; a description of the post-and-core systems tested; and information about detectable survival or success of the selected teeth. After the application of these criteria, 10 in vitro studies and 6 clinical investigations remained.

For the in vitro studies, load-to-failure was defined as the primary outcome for comparison purposes. A meta-analysis of the fracture loads was conducted only on data related to cast posts and cores or direct cores with metal posts. These data came from 4 studies in which maxillary central or lateral incisors and maxillary and mandibular canines had been used for fabrication of the specimens. Weighted means and standard deviations were used to combine the results of the studies into overall means. A *t*-test was then applied to identify significant differences between the 2 treatment modalities.

For the in vivo studies, failure was defined as the need for recementation, a new restoration of any kind, or extraction of the tooth. Because of the nature of data presentation within the original reports, no overall combination of the survival data was possible.

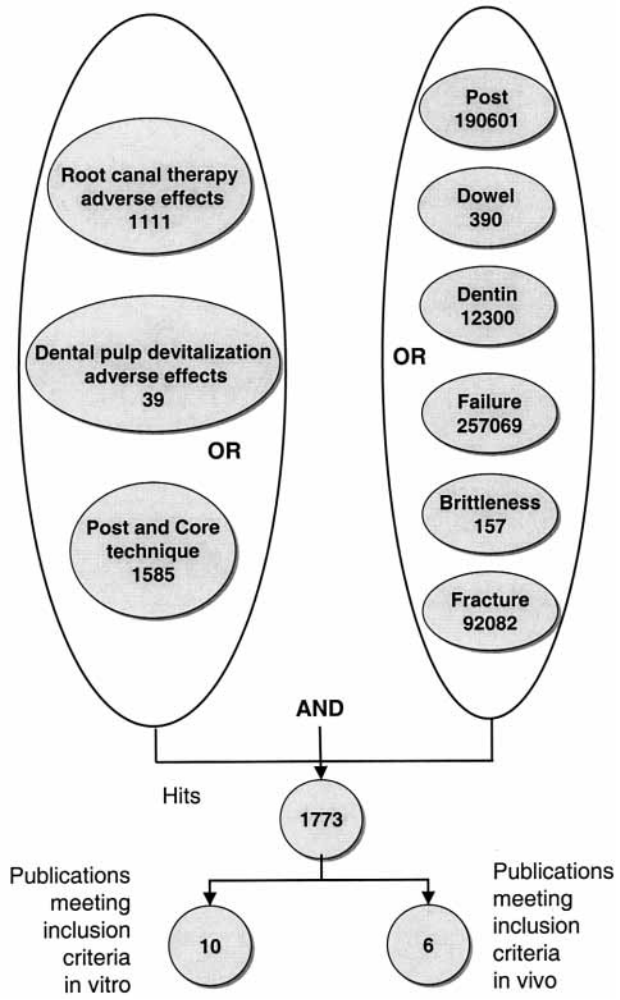

Fig. 1. Combination of keywords and subject headings used in literature search (7/2000).

IN VITRO STUDIES

Of the 10 in vitro studies included in this review,[9-18] 2 used premolar teeth as abutments and 2 reported failures after only cyclic loading (no static loading). All studies except 1 reported the mode of fracture.

Akkayan and Caniklioglu[9] compared tapered, custom-made cast posts and cores to direct cores that were built up from prefabricated tapered or parallel posts and silver-reinforced glass-ionomer cement. Freshly extracted maxillary canines were used in this study. A screw-type anchor was tested but is not considered in this review because no other in vitro studies used screw-type posts. After single crowns were fabricated, the specimens were loaded to fracture. Significant differences were found among the fracture loads of the 3 test groups. Higher loads were observed for direct core restorations. The predominant mode of failure was vertical root fracture in the cast post-and-core group. Direct cores fractured horizontally; deeper fracture was associated with the tapered system.

Assif et al[10] used single-rooted premolars with similar dimensions to compare custom-tapered and prefabricated parallel posts. All posts were cast in a base metal alloy, and complete cast crowns were fabricated and cemented. All specimens were loaded to failure. The mode of failure was deep horizontal fracture, with no significant differences between the test groups.

Butz et al[11] compared the failure loads of different post systems subjected to thermomechanical fatigue. Cast posts and cores were fabricated from tapered cast-on prefabricated posts. The direct cores were made from tapered titanium posts with dimensions identical to those of the cast posts. The resin cores were completed with an autopolymerizing hybrid composite. After complete cast incisor crowns were seated, all specimens were subjected to cyclic loading. One specimen in each group failed. The remaining seven specimens in each group were loaded to failure. The differences in failure loads were not significant; a deep oblique root fracture was observed in both test groups.

Kern et al[12] used the same post system to create a

Table I. Summary of information from selected studies

Study	Selected for meta-analysis	Testing procedure	Sample size		Failure level	
			Cast P/C	Direct P/C	Cast P/C	Direct P/C
Akkayan and Caniklioglu[9]	Yes	Static loading	10	10/10*	822 N	1053 N
Assif et al[10]		Static loading	10		2542 N	
Butz et al[11]	Yes	Cyclic and static loading	16	16	426 N	425 N
Kern et al[12]	Yes	Static loading	10		553 N	
Martinez-Insua et al[13]		Static loading	22	22†	2027 N	1037 N
Perez Moll et al[14]		Static loading	30		419 N‡	
Sidoli et al[15]		Static loading	10	10	15.3 MNm^{-2}	14.2 MNm^{-2}
Robbins et al[16]	Yes	Static loading		10/10*		530 N
Isidor and Brondum[18]		Cyclic loading	12	12	22,700 cycles	95,000 cycles
Isidor et al[17]		Cyclic loading		14		>260,000 cycles

P/C = Post and core.
*Equal numbers of specimens with tapered and parallel posts were reported.
†Carbon-fiber posts (excluded from meta-analysis).
‡No standard deviations reported.

Table II. Meta-analysis of the fracture loads for cast posts and cores and direct cores

	Cast P/C	Direct P/C	*t* Test
n	36	56	
Mean (N)	571.3	601.3	
95% CI (N)	521.1 / 621.4	575.0 / 627.5	
SD (N)	153.5	100.4	
SE (N)	25.6	13.4	
Difference of the means			29.97
Pooled variance			830369.0
t Value			0.1540
P Value			.8780

P/C = Post and core; *CI* = confidence interval; *SD* = standard deviation; *SE* = standard error.

group of cast posts and cores. The central incisor teeth were restored with all-ceramic crowns and loaded to failure. Most failures in the cast post group manifested as vertical root fractures.

Martinez-Insua et al[13] compared single-rooted premolars restored with a custom-made parallel cast post and core (control) or with a carbon-fiber post and composite core. The cast post-and-core group withstood significantly higher fracture loads, but most fractures involved the tooth. Fractures in the carbon-fiber group involved the cores only and were repairable.

Perez Moll et al[14] investigated the difference between pin-retained amalgam cores and custom cast posts for the restoration of centrals, lateral incisors, and canines. The authors reported lower fracture load values for the cast posts, but these values were within the range reported in the other studies reviewed here. Interestingly, no root fractures were observed in the Perez Moll et al[14] investigation. All posts and cores were dislodged from the root canals. Unfortunately, the authors did not report standard deviations for their measurements.

Using maxillary central incisors and mandibular canines, Sidoli et al[15] compared parallel stainless steel or carbon-fiber posts with composite cores to cast posts and cores. Failure loads were not reported, but no significant difference was found in the stress at fracture of cast cores and direct cores supported by metal posts. Carbon-fiber post-retained cores withstood significantly lower stress levels. These restorations fractured above tooth level; in the other 2 test groups, the majority of failures were deep, horizontal fractures.

Robbins et al[16] compared tapered and parallel posts for the retention of direct amalgam core buildups. There was no difference in the fracture loads of mandibular and maxillary canines restored with single crowns. Unfortunately, the authors did not report the mode of failure for any specimens.

Isidor et al[17,18] used cyclic loading to compare tapered, custom cast posts and cores to direct cores with a parallel metal or carbon-fiber post in bovine teeth. Teeth restored with cast metal posts fractured after significantly fewer cycles than teeth with direct cores. The number of cycles before failure was higher for teeth restored with carbon-fiber posts and composite cores. Deep oblique fractures dominated the metal post-and-core group, whereas horizontal fractures dominated the direct core and metal post group. The authors did not classify the vertical cracks in the carbon-fiber post group as failures.

Table I provides a summary of the fracture loads or cycles to failure reported in the selected in vitro studies. The results of 4 studies[9,11,12,16] were evaluated with a meta-analytic procedure. In each of these studies, anterior teeth were used, metal posts were tested, testing was performed under static conditions, and sufficient data were reported to allow secondary analysis.

For the 2 studies that used both tapered and parallel posts for direct buildups,[9,16] both modalities were included in the calculation to compensate for different post geometries. Weighted means and standard deviations were computed according to sample size. The computed means were compared with the use of 95% confidence intervals and a *t*-test. The intersection of the confidence interval indicated a nonsignificant difference between the 2 experimental conditions, which was confirmed with the *t*-test (Table II).

The modes of failure are summarized in Table III. For both restorative techniques, most fractures occurred at mid-root or in the apical third. Only teeth restored with carbon-fiber posts typically fractured above the acrylic support jigs, leaving the teeth in a restorable condition.

As mentioned previously, the application of inclusion criteria eliminated the majority of the 1773 publications originally identified as pertinent to the topic. Many reports described the testing of different post/core combinations in single-rooted teeth, but very few involved a clinically meaningful test situation. When a clinical crown is fully lost, a complete crown is almost always required for the functional and esthetic rehabilitation of a tooth. It has been argued that the cementation of a crown over any endodontic restoration would blur the differences between different treatment modalities and consequently not allow their comparison.[19] A different conclusion could be drawn, however: that there is actually little difference between the wide range of post designs and systems when a complete-crown restoration is performed. Fracture resistance may be more dependent on the amount of remaining sound dentin ferruled by the crown restoration.[20,21] This is highlighted by the fact that in several studies, the best results were recorded for control groups in which otherwise sound teeth were endodontically treated and crowned without a posted restoration.[10,21,22] To better reflect real clinical situations, only studies that used complete crowns were selected for this review.

In most in vitro studies, a static loading test was used to induce failure. An anatomic load angle of 130 to 135 degrees[23] was almost always used to test the specimens. This homogeneity is crucial for a comparison of results across studies.[24] While the application of static force does not necessarily simulate actual intraoral loading,[25] the general hypothesis is that it would at least detect differences between treatment modalities with regard to strength. Studies that simulate clinical conditions with fatigue loading would be more clinically relevant,[25] but they are scarce, often do not incorporate both cast and direct post restorations, and present data in different ways.

Careful screening of test conditions in the 10 reviewed in vitro studies allowed for a meta-analytic comparison of cast and direct post restorations across 4 studies. The results indicated that neither treatment modality is superior. The same result was reported independently in in vitro studies that compared cast and direct posts with static or cycling loading tests.[11,16] While an advantage for direct cores was observed in one cyclic loading study,[18] it can be argued that different post geometries were responsible for the observed difference. Tapered cast posts have been blamed for a wedging effect and lower failure loads, but the results are inconsistent across studies. In 2 studies, no differences were observed between tapered and parallel designs when direct or cast posts and cores were created.[10,16] In a different investigation, slightly higher failure loads were reported for tapered designs.[9] To compensate for the possible influence of different post designs, data on both tapered and parallel posts from Akkayan and Caniklioglu[9] and Robbins et al[16] were included in the meta-analysis.

Table III. Comparison of fracture modes

Study	Cast P/C	Direct P/C
Akkayan and Caniklioglu[9]	Vertical	Deep horizontal
Assif et al[10]	Deep horizontal	
Butz et al[11]	Deep oblique	Deep oblique
Isidor and Brondum[18]	Deep oblique	Horizontal
Isidor et al[17]		Vertical (CFP)
Kern et al[12]	Deep oblique	
Martinez-Insua et al[13]	High oblique	Core fracture (CFP)
Perez-Moll et al[14]	Dislodgement	
Robbins et al[16]		
Sidoli et al[15]	Deep horizontal	Deep horizontal

P/C = Post and core.

Tooth fractures associated with post-and-core failure frequently render the tooth non-restorable and necessitate its extraction. However, if fractures occur in a coronal section of the root, repair may be possible. Favorable modes of fracture involving only the core have been reported for post/carbon-fiber core combinations.[13] Fatal vertical cracking also has been reported, however.[17] The primary disadvantage of carbon-fiber posts seems to be their low mechanical resistance. At the same time, this characteristic may also be considered advantageous because it results in less stress during static and cyclic loading.[15,17]

In the in vitro studies reviewed here, there was little difference in fracture mode between cast and direct core buildups with metal posts. A statistical comparison of the fracture modes was not possible due to inconsistent reporting, but a descriptive evaluation revealed no predominant mode of failure. Unfortunately, the rigidity of both restorative approaches seems to trigger deep, oblique horizontal

Table IV. Summary of in vivo studies on anterior teeth

Study	Follow-up (yrs)	Total sample	Sample size		Success (%)		Comment
			Cast P/C	Direct P/C	Cast P/C	Direct P/C	
Bergman et al[26]	6	96	39 custom		87.2		Survival detectable
Hatzikyriakos et al[27]	3	187	33	41 S, 28 PP	93.0	90.3 S, 89.3 PP	Success calculated
Linde[28]	9.5	59	0	27 S		67.9	Compromised teeth
Mentink et al[29]	8	112	0	25 S		92.0	3 different types of screws
Mentink et al[30]	4.8	516	206 Permador	0	88.9		Survival detectable
Torbjörner et al[31]	4-5	788	422	0	92.5		Success calculated

P/C = Post and core; *S* = screw; *PP* = ParaPost.

or even vertical fractures.[11,15] In a clinical situation, most teeth with these types of fractures would be lost.

IN VIVO STUDIES

In 1993, Creugers et al[8] conducted a meta-analysis of clinical studies on the success of post-and-core restorations. No randomized controlled trials were available for that review. Unfortunately, the same was true when the current review was initiated some 7 years later.

The results of 6 in vivo studies are reported here, starting with Bergman et al,[26] who conducted a retrospective investigation of 96 custom-made, tapered cast posts and cores. Thirty-nine of these were located in anterior teeth. A total of 9 failures were recorded, 5 in anterior teeth. The failures constituted either loss of retention requiring recementation of the post and core or root fractures. A survival rate of 87.2% was reported for anterior teeth after 6 years.

Hatzikyriakos et al[27] collected data on 154 posts and cores from 150 patients. Sixty-nine direct buildups were fabricated with Dentatus screws (Dentatus AB, Hagersten, Sweden) or ParaPost steel dowels (Coltene/Whaledent, Mahwah, N.J.) and completed with composite. Thirty-three cast posts and cores were fabricated. After an observation period of 3 years, 3 failures of the anterior cast posts and cores were recorded, resulting in a survival rate of 93%. The combined survival rate for direct cores was 89.9%. Four failures occurred with screw posts, and 3 ParaPosts were lost.

A sample of 59 Dentatus screw posts in 27 anterior teeth was reviewed by Linde,[28] who recorded 19 failures. The survival rate after an observation period of 9.5 years was 67.9%. The author emphasized, however, that treatment with screw posts was chosen for abutments with questionable prognosis to avoid the otherwise necessary extraction.

Mentink et al[29] evaluated direct cores placed with 3 different types of screw anchors in one study and tapered cast posts and cores in another.[30] In the first of these investigations, 92% of the 25 screws used for the restoration of anterior teeth survived after a mean follow-up period of 8 years.[29] In the second investigation, a distinction was drawn between fixed partial denture teeth and single crown abutments. Survival rates of 88% and 82.5% were estimated for abutment teeth after 4.4 years and solitary crowns after 9.6 years, respectively.

Torbjörner et al[31] evaluated parallel cast posts and cores in 422 anterior teeth after 4 to 5 years of service. No life table was provided in this study, but a 92.5% success rate could be deduced from the data on metal cores in anterior teeth.

The conditions and results of these 6 studies are summarized in Table IV. Differences in data reporting did not allow a meta-analysis of the results. The reconstruction of failure was inhibited primarily by the fact that in half of the studies, no information on the survival of individual abutments was provided. An overall numerical statement for the survival of cast or direct core restorations for anterior teeth therefore could not be made. In 3 studies, individual tooth failures were reported and life tables enabled the estimation of survival.[26,28,30] The separate data on single crown and fixed partial denture abutments reported in Mentink et al[30] were combined into one survival analysis. Since the observation time in 1 of the 3 studies did not exceed 6 years,[26] a comparison of the survival rates seemed feasible for only a 6-year period. The survival for cast posts and cores in 2 studies ranged from 87.2% to 88.1%[26,30] and in the third study reached 86.4% for direct cores after 72 months.[28] The survival curves are presented in Figure 2.

A decrease in survival after the 6-year mark was reported by Linde.[28] The author emphasized, however, that in his study population direct core restorations were fabricated for teeth that otherwise would have been extracted. He reported that 27% of the abutment teeth had periodontal pockets ≥4 mm. Diminished bone support may have triggered preliminary failure.[32] Moreover, a sufficient ferrule effect may have been difficult to achieve in shorter roots.[21] Hatzikyriakos et al[27] and Mentink et al[29] reported more favorable fail-

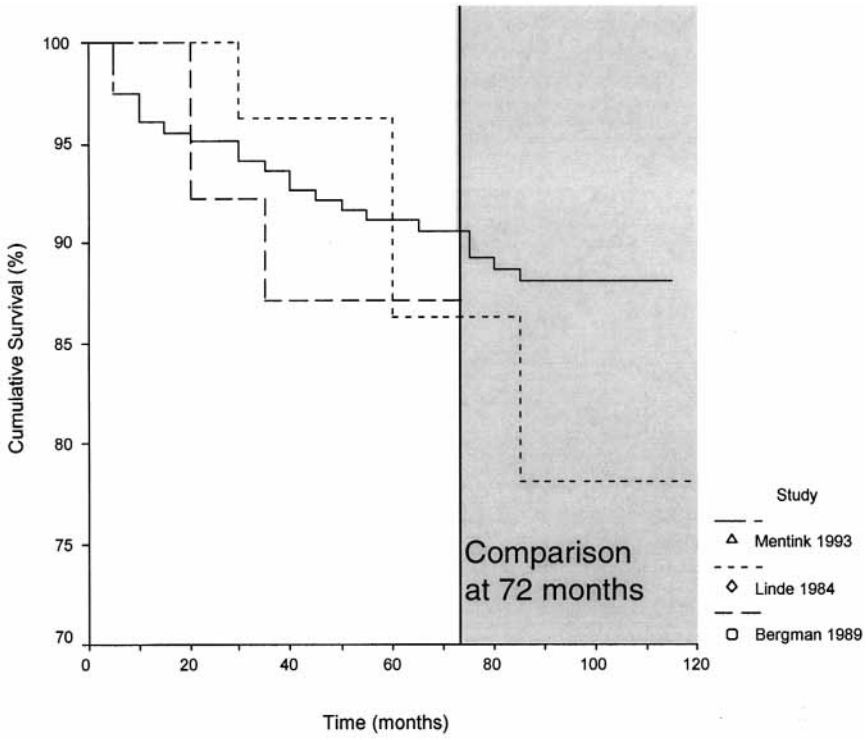

Fig. 2. Survival rates for anterior teeth in 3 studies. Because observation period in 1 study did not exceed 72 months, this time point was chosen for comparative purposes.

ure rates for direct cores (8% to 11% after 3 to 8 years), but these results may be attributable to the shorter observation time and better condition of the abutment teeth.

Very little clinical data are available on post-and-core treatments that are performed on a daily basis. This fact, combined with the inconsistency of the clinical data that have been published, makes it impossible to deem either cast or direct post-and-core restoration superior to the other. Both treatment modalities can be recommended if they are applied within the indications and with the necessary caution.

SUMMARY

Based on the 10 in vitro and 6 in vivo studies reviewed, no conclusive evidence favors cast over direct post-and-core restorations or vice-versa. The traditional cast post-and-core technique is more time consuming and frequently involves greater laboratory and material costs. If the quality of treatment is comparable, direct core restorations can reduce both time and financial burdens on the patient. The body of literature on the clinical success of post-retained cores is scarce. Randomized controlled trials are needed. Future laboratory studies should focus on which treatment modality is appropriate for teeth with different degrees of hard tissue loss.

Future in vitro research should be conducted under standardized conditions and protocols.

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