

Clinically significant factors in dowel design

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The dental literature is replete with techniques for the restoration of endodontically treated teeth. However, conflicting *in vitro* studies offer few guidelines for efficient dowel and core systems. The lack of clinical research has rendered to tradition and clinical impressions the selection of a method, with limited documentation of its effectiveness.

Previous research demonstrated that no significant increase in resistance to failure by fracture or dislodgment is gained with the placement of a dowel in pulpless teeth.¹ *In vitro* studies suggest that it is the bulk of the remaining tooth structure rather than the dowel that provides strength and resistance to fracture for the endodontically treated tooth.²⁻⁴ When inadequate tooth structure remains for retention of a restoration, a method that replaces dentin and forms a foundation must be used. A variety of techniques that range from a coronal-radicular amalgam core to a dowel and core have been used as a foundation for coronal coverage of posterior teeth.⁵⁻⁹ In anterior teeth the placement of a dowel and core serves as a satisfactory retainer of restorative materials for crown preparation.¹⁰⁻¹²

The purpose of this evaluation of 1273 endodontically treated teeth was to (1) compare the clinical success rate of six coronal-radicular stabilization methods, (2) record the failure of dowel systems and the effect on endodontically treated teeth, and (3) determine the effect of dowel length on the clinical success rate.

LITERATURE REVIEW

Many authors insist that placement of a cast dowel and core is the treatment of choice for the restoration of endodontically treated teeth,¹⁰⁻¹⁸ while others advocate a

prefabricated post and composite resin core or amalgam core.^{7-9, 19, 20} Although placement of pin-retained composite resin cores has become popular,²¹⁻²⁴ self-threading pins in nonvital teeth have been criticized because of the tendency to cause dentinal crazing and fractures.²⁵⁻²⁸ The use of self-threading pins in conjunction with a prefabricated post has also been promoted.^{24, 29, 30} Finally, the use of composite resin^{20, 31} or amalgam^{5, 6} as a core restoration has been advocated.

Laboratory studies have yielded conflicting results in the determination of the strongest and most retentive intracoronal reinforcement technique. Some *in vitro* studies have shown pin-retained amalgams and composite resins to be stronger than cast dowels and cores.^{29, 32, 33} while one study found that cast dowels and cores were superior.³⁴

In a study with freshly extracted mandibular premolars, Chan and Bryant³⁵ determined that cast-gold dowels and cores demonstrated a significantly lower mean failure load than amalgam or composite resin cores with a cemented Parapost (Whaledent International, New York, N.Y.).

In vitro studies have shown that the important variables of the dowel in a dowel and core system are design, length, surface configuration, and diameter.

The superior retentive abilities of a parallel-sided dowel over a tapered dowel to resist tensile, shear, and torque forces were demonstrated by Standlee et al.³⁶ and others.^{29, 37} Johnson and Sakamura³⁸ found parallel-sided dowels to resist tensile forces 4.5 times greater than tapered dowels. *In vitro* studies of simulated trauma have shown an advantage in parallel-sided posts.^{4, 34} Colley et al.³⁷ demonstrated with extracted teeth that in tension a parallel-sided serrated post 5.5 mm in length was more retentive than a tapered post 8 mm long.

Tapped threaded posts exhibit greater resistance to displacement against tensile forces compared with nonthreaded post systems, but they are difficult to place.^{39, 40} Self-threading or screw post systems are capable of producing extremely high stress levels and root fracture.^{27, 41} Investigators encountered frequent cracking and fracture of specimens and taps.^{41, 42} The

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Table I. Prevalence of intracoronal reinforcement method and success rate

Method	Total		Success		Failure	
	No.	%	No.	%	No.	%
No reinforcement	832	65.4	748	89.9	84	10.1
Cast Parapost and core	38	3.0	38	100	0	0
Parapost and amalgam or composite resin core	132	10.4	129	97.7	3	2.3
Pin-composite resin core	13	1.0	12	92.3	1	7.7
Tapered cast dowel and core	245	19.2	214	87.3	31	12.7
Pin-amalgam core	8	0.6	6	75.0	2	25.0
Threaded post	5	0.4	3	60.0	2	40.0

high stresses involved during the tapping procedure and delivery increase risk of fracture⁴¹⁻⁴⁴ and rendered this method a poor alternative for restoration of endodontically treated teeth.

With photoelastic models, Standlee et al.⁴¹ illustrated that tapered posts created a wedging effect with the greatest shoulder stress concentrations, while smooth-sided parallel posts generated the maximum apical stresses.

Standlee et al.³⁶ believed that dowel design was responsible for the following in vitro failures: (1) tapped threaded posts failed by dentinal fracture, usually with one longitudinal split in the long axis of the root; (2) the parallel-sided serrated vented dowel was dislodged, with most of the cement adhering to the dowel; and (3) the smooth tapered post left cement in the channel and failed at the post-cement interface.

Chan and Bryant³⁵ discovered that freshly extracted mandibular premolars with cast-gold posts and cores under compressive loads failed by displacement and root fracture. The Parapost and amalgam or composite resin specimens usually demonstrated fracture of the core but exhibited fewer post-core dislodgments and root fractures.

Kantor and Pines³⁴ examined restorative techniques for pulpless teeth. In single-rooted teeth the composite core fractured from both the tooth and the stainless steel rod. The cast-gold post and core split the tooth vertically, while the cemented-pin group fractured apical to the cemented pins.

Many investigators have demonstrated a significant relationship between vertical resistance to displacement and length of the dowel.^{30, 36, 37, 45} Johnson and Sakamura's³⁸ results indicated that an increase in length of the dowel from 7 to 11 mm increased retention by 30%. Increased root length and subsequent post length have been shown to produce significantly greater resistance to fracture.⁴ In photoelastic tests a reduction of stress concentration was also observed with increased post length.⁴¹

The decision regarding the length of the dowel has been based on clinical tradition. Various guidelines have been suggested for optimum dowel length. It should be (1) equal to half the length of the remaining root,^{24, 46} (2) equal to two thirds of the root length,^{47, 48} (3) equal to the length of the clinical crown,^{13, 17, 24, 41, 46-51} (4) have 3 mm of gutta-percha for an apical seal and be extended as long as possible,^{49, 51} and/or (5) half the length of the root contained in bone.¹¹

Current studies reveal no significant effect on the apical seal when 4 mm or more of gutta-percha remains in the apical portion of the canal.⁵²⁻⁵⁴ Therefore, dowel length is recommended to attain as great a length as possible with a minimum of 4 mm of undisturbed gutta-percha for an apical seal. This goal must be balanced by the knowledge that overpreparation of the dowel space may cause root perforation^{3, 55} or weaken the tooth by decreasing the bulk of dentin^{2-4, 55} and reduce the resistance to fracture.

Surface configuration is another critical variable in dowel retention. Standlee et al.³⁶ and others^{30, 37} have recorded a marked increase in retention with roughened or serrated posts. Colley et al.³⁷ demonstrated that serrated posts 3.5 mm in length had two to three times greater retention than smooth posts of equal length. Ruemping et al.³⁰ found in vitro surface configuration of a dowel was more important than length in retention.

Two investigations of varying dowel diameter had minimally significant effect on the retentive ability of a dowel.^{36, 43} Endodontically treated teeth that were restored with smaller diameter stainless steel posts provided increased resistance to fracture compared with larger post sizes.⁴ A photoelastic study demonstrated that greater post diameter increases stress in the radicular portion of the tooth and that excessive removal of tooth structure may lead to increased stress.³ One study showed the strength of an endodontically treated tooth to be directly related to the bulk of remaining dentin.²

Table II. Manner of failure for each method of intracoronary reinforcement

Method	Manner of failure											
	Aggregate failure rate		Restorable						Nonrestorable (extracted)			
			Dislodgment		Tooth fracture		Tooth fracture		Vertical root fracture		Iatrogenic root perforation	
			No.	%	No.	%	No.	%	No.	%	No.	%
No reinforcement	84	10.1	2	2.4	50	59.5	22	26.2	10	11.9	—	—
Cast Parapost and core	0	0.0	—	—	—	—	—	—	—	—	—	—
Parapost and amalgam or composite resin core	3	2.3	2	66.7	—	—	—	—	—	—	1	33.3
Pin-composite resin core	1	7.7	—	—	1	100	—	—	—	—	—	—
Tapered cast dowel and core	31	12.7	11	35.5	8	25.8	6	19.4	4	12.9	2	6.5
Pin-amalgam core	2	25.0	—	—	1	50.0	—	—	1	50.0	—	—
Threaded post	2	40.0	—	—	—	—	—	—	2	100	—	—

Table III. Success and failure rate associated with dowel length

Dowel length*	Success		Failure	
	No.	%	No.	%
No dowel	766	89.8	87	10.2
¼	36	75.0	12	25.0
⅓	53	81.5	12	18.5
½	40	85.1	7	14.9
¾	197	97.5	5	2.5
1¼	21	100	0	0
1½	34	100	0	0
1¾	—	—	—	—
2	3	100	0	0

*Measured in increments of one fourth of crown length.

A review of the literature reveals that the significant in vitro factors of dowel fabrication are design, length, surface configuration, and diameter. Few investigations determined the clinical significance of these factors. This study will consider the clinical significance of the variables in the success of endodontically treated teeth. The clinical success rate of the intracoronary reinforcement methods will also be compared.

METHODS

Over 6000 patients records of nine dentists in general practice were examined for endodontically treated teeth. The teeth were examined and compared by means of the independent variables of intracoronary

reinforcement method, dowel length, and manner of failure.

Intracoronary reinforcement method. Endodontically treated teeth were divided into categories by intracoronary reinforcement technique. The categories included (1) tapered cast dowel and core, (2) Parapost and amalgam or composite resin core, (3) cast Parapost and core, (4) threaded post, (5) pin-amalgam core, and (6) pin-composite resin core.

Dowel length. The length of the dowel was determined radiographically. Dowel length was recorded as a ratio to the nearest one fourth of crown length.

Manner of failure. Recorded failures of endodontically treated teeth were differentiated into two groups: those considered restorable because of failure by dislodgment or tooth fracture and those considered nonrestorable and extracted because of failure by tooth fracture, vertical root fracture, and iatrogenic root perforation.

All treatment reported in patient records was verified radiographically. Teeth were not included in the study if present for less than 1 year, although history of failures was noted from the day of root canal therapy. Endodontically treated teeth with a history of failures because of periodontal pathosis or carious involvement were also excluded. Based on these guidelines, 1273 endodontically treated teeth were selected from 6000 patient records.

Patient records were reviewed for information from

Table IV. Distribution of dowel lengths for each method

Method	Dowel length															
	$\frac{1}{4}$		$\frac{1}{2}$		$\frac{3}{4}$		$\frac{4}{4}$		$1\frac{1}{4}$		$1\frac{1}{2}$		$1\frac{3}{4}$		2	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Cast Parapost and core	—	—	—	—	5	13.2	22	57.9	7	18.4	3	7.9	—	—	1	2.6
Parapost and amalgam or composite resin core	1	0.8	4	3.0	17	12.9	75	56.8	12	9.1	21	15.9	—	—	2	1.5
Tapered cast dowel and core	47	19.2	61	24.9	24	9.8	102	41.6	1	0.4	10	4.1	—	—	—	—
Threaded post	—	—	—	—	1	20.0	3	60.0	1	20.0	—	—	—	—	—	—
Total	48	11.4	65	15.5	47	11.2	202	48.1	21	5.0	34	8.1	—	—	3	0.7

*Measured in increments of one fourth of crown length.

office visits subsequent to endodontic therapy and the last recorded examination. The definition of clinical success was based on the absence of negative findings at the dentist's last examination.

RESULTS

The data are presented in a series of tables. Table I exhibits the prevalence of each procedure and the clinical success rate of each method of intracoronar reinforcement encountered in the study. For the purpose of comparison, the success and failure rate of no intracoronar reinforcement is presented as the first entry in the table. Almost two thirds (65.4%) of the endodontically treated teeth in this sample did not have intracoronar reinforcement. The success rate for teeth without coronal-radicular stabilization was 89.9%. Of the teeth with intracoronar reinforcement, tapered cast dowels and cores were the most frequent methods used (19.2%) and possessed a success rate of 87.3%. Parapost and amalgam or composite resin core reinforcement was used in 10.4% of the teeth and resulted in a more impressive success rate of 97.7%. The remaining reinforcement methods (cast Parapost and core, pin-composite resin, pin-amalgam, and threaded post) were used in 5% of the endodontically treated teeth. However, it is noteworthy that the 38 teeth with a cast Parapost and core were 100% successful. Pin-amalgam and threaded post reinforcement techniques were the least successful and accounted for less than 1% of the reinforcement methods.

Table II lists the six methods of intracoronar reinforcement and their respective number and type of failure. The aggregate failure rates and percents of types of failure are listed for each reinforcement method. The success and failure rate of teeth without intracoronar reinforcement is presented for comparison in Table II. The reinforcement methods are organized in the table from least to greatest failure rate. For

further clarification the manner of failures were classified as restorable teeth (dislodgment or tooth fracture) and nonrestorable teeth that required extraction (tooth fracture, vertical root fracture, or iatrogenic root perforation). Failures were relatively few in number and prevent generalization because of the small sample size; however, most failures (61%) were restorable. Of the endodontically treated teeth without intracoronar reinforcement, 97.6% failed because of fracture, with 59.5% being restorable. The tapered cast dowel and core method failed 61.3% of the time in a restorable fashion, while 39% resulted in extraction.

Table III presents the success and failure rate for dowels of varying lengths. Dowel length is listed in increments of one fourth of crown length. The data exhibit a direct correlation between the length of the dowel and the clinical success rate. Without dowel placement the success rate was 89.8%, whereas when the dowel length was less than three fourths of the crown length, the success rate was less than 85.1%. However, when dowel length equaled crown length, the success rate was 97.5%. Dowel length greater than crown length recorded a success rate of 100%.

Table IV indicates the distribution of dowel length for each of the dowel techniques. Paraposts had median values for their length greater than the crown length. The median values of the tapered cast dowel and cores were less than the crown length.

DISCUSSION

As expected from in vitro studies,^{29, 30, 34, 36-38} parallel-sided serrated dowels were the most clinically successful intracoronar reinforcement. The cast Parapost and core technique with a 100% success rate was slightly more successful than the Parapost and amalgam or composite resin core technique, with a 97.7% success rate. Although parallel-sided serrated dowels were more successful, they were not the technique most often

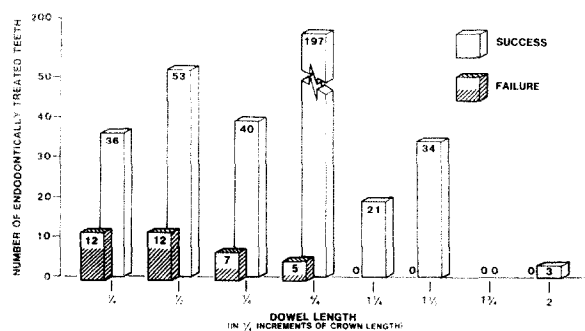


Fig. 1. Distribution of endodontically treated teeth associated with dowel length.

used, and they accounted for only 13.4% of endodontically treated teeth in the study.

The sample size of the pin-composite resin core technique was too limited for definitive statements, but the success rate of 92.3% was greater than that of other treatment.

The clinical success rate of tapered cast dowels and cores (87.3%) was less than endodontically treated teeth without intracoronal reinforcement (89.9%). The tapered cast dowel and core technique was most often used by the dentists in this study (19.2%). The fact that the failure rate of tapered cast dowel and cores exceeded that of the group of teeth without intracoronal reinforcement conflicted with the findings of our previous study,¹ which reported that there was no significant increase in resistance to fracture or dislodgment gained with the placement of a dowel in a pulpless tooth.¹ However, if the tapered cast dowel and core technique was excluded from the study,¹ then the placement of a dowel would have appreciably increased the clinical success rate.

The pin-amalgam core technique had a high failure rate of 25%, but the small sample size restricted conclusive statements.

As anticipated from laboratory studies,⁴¹⁻⁴⁴ self-threading or screw post systems had an excessive failure rate of 40%. The sample size for this group was also insufficient for conclusive statements. The potential damage inflicted on the tooth by possible failure of the dowel system must be considered when an intracoronal reinforcement method is selected.

The few failures of the Parapost system made the sample size small. However, two thirds of the Paraposts failed by dislodgment, while one pin-composite resin core failed by restorable tooth fracture. Approximately 62% of endodontically treated teeth without intracoronal reinforcement failed but were restorable, and 38% failed necessitating extraction. The tapered cast dowel and core technique failed approximately

Table V. Comparison of anatomic crown length and root length (in millimeters)

	Anatomic crown	Root
Maxillary		
Central incisor	10.5	13.0
Lateral incisor	9.0	13.0
Canine	10.0	17.0
First premolar	8.5	14.0
Second premolar	8.5	14.0
First molar	7.5	B-12.0, L-13.0
Second molar	7.0	B-12.0, L-13.0
Mandibular		
Central incisor	9.0	12.5
Lateral incisor	9.5	14.0
Canine	11.0	16.0
First premolar	8.0	14.0
Second premolar	8.0	14.5
First molar	7.5	14.0
Second molar	7.0	13.0

From Wheeler, R.: Dental Anatomy, Physiology and Occlusion, ed. 5. Philadelphia, 1974, W. B. Saunders Co

61% of the time in a restorable fashion, and 39% of the teeth had to be extracted. Two pin-amalgam cores failed, requiring extraction. Both threaded posts failed by vertical root fracture and needed extraction.

Although the sample size restricts generalization, the data indicate that intracoronal reinforcement fails for a variety of reasons. Contrary to two in vitro studies where smooth tapered posts were removed cleanly from the tooth,^{36, 38} failures of the tapered cast dowel and core caused angular and vertical root fracture that resulted in extraction. Standlee et al.⁴¹ also demonstrated that tapered posts exhibited a wedging effect in photoelastic models.

Many of the angular and vertical root fractures can be attributed to hydraulic pressures induced during cementation of tapered cast dowel and cores. The Parapost system is vented to release pressure during cementation.

Caputo and Standlee⁵⁰ suggested that the parallel-sided serrated cemented dowels act as intermediate retainers and distribute stresses evenly through the root structure. In the small number of failures that did occur, most parallel-sided serrated dowels failed by dislodgment, which allowed retreatment. No angular or vertical root fractures were observed with the parallel-sided dowel.

That all threaded posts failed by vertical root fracture was predictable from in vitro investigations in which high stress levels were observed associated with installation and frequent root fracture.^{36, 41-44}

There was a marked increase in the success rate of

endodontically treated teeth when the length of the dowel was equal to or greater than the crown length (Fig. 1). When the dowel length was less than the crown length, the failure rate exceeded that of teeth without a dowel. There were no failures in pulpless teeth with dowel lengths greater than the crown length. However, the goal of maximum dowel length must be mediated by the amount of remaining tooth structure, canal and root morphology, and the risk of perforation during dowel space preparation.^{2-4,55} When conditions permit, dowel length should be as long as possible with 4 mm or more of gutta-percha for an apical seal.^{53,54}

Obtaining a dowel length that is equal to the crown length may not be possible. Wheeler⁵⁷ lists the average crown length of a maxillary central incisor as 10.5 mm and the root length equal to 13 mm. Therefore, by allowing 4 mm of gutta-percha for an apical seal, a dowel length equal to the crown length is not possible. Table V lists average crown and root lengths. Studies indicate that if the dowel length must be compromised, a parallel-sided serrated cemented dowel will be more retentive than a tapered smooth dowel.^{29,36,38}

Table IV indicates the distribution of dowel lengths for each of the dowel techniques. Parapost lengths were distributed so that the median value was greater than the crown length. The median value of the tapered cast dowels and cores was less than that of the crown length. In addition to the other advantageous features of a parallel-sided serrated dowel, the greater median length contributes to a higher success rate. Preparation of space for a parallel-sided dowel at longer lengths is easier than for a tapered dowel.

Opponents argue that prefabricated parallel-sided round dowels are not well suited for teeth with conical or ribbon-shaped canals.³⁶ The mismatch between dowel and channel is purported to increase cement thickness and increase dependence on the luting agent for retention. This observation and our previous study¹ show that retention is important, but resistance to fracture is crucial. Perhaps the dowel can be too closely adapted to the channel and fracture the tooth when the systems fail. The custom-tapered cast dowel and core was shown in this study to have a higher frequency of irreversible damage to the tooth on failure than the prefabricated parallel-sided serrated dowel. In light of the findings, the cement could act as a stress buffer, and maximum adaptation of the dowel to the channel is not desirable.

Opponents of the parallel-sided serrated dowel technique claim that preparation of a parallel-sided channel is accompanied by a high risk of perforation. However, with the knowledge of the root morphology and the importance of the bulk of dentin to the strength

of the pulpless tooth, the diameter of the dowel can be minimized and the chances of success increased.

Judicious use of hot instruments and/or non-end cutting Gates-Glidden drills (Union Broach Co., Inc., Long Island City, N.Y.) are suggested for adequate removal of gutta-percha in preparation for a round post space without perforation.

When the length of the dowel is limited by a curved root canal or short root length, the parallel-sided serrated dowel is recommended for treatment because it is more retentive at shorter lengths than the tapered cast dowel and core.

SUMMARY

When a method of intracoronal reinforcement is selected, many factors must be weighed. The hazards include (1) the induced stresses and the risk of fracture during placement of the dowel, (2) the probability of root perforation during post space preparation, (3) the wedging action of tapered dowels, and (4) the incidence of fracture with self-threading pins in devitalized teeth.

The amount of tooth structure that remains after endodontic therapy and post space preparation is paramount. Endodontic and restorative treatment must be aimed at preserving tooth structure to provide strength and resistance to fracture of the pulpless tooth. To fabricate a large-diameter dowel with a strength that greatly exceeds that of the endodontically treated root decreases the prognosis for clinical success.

CONCLUSIONS

For the 1273 endodontically treated teeth evaluated in this study the following observations were made.

1. The cast parallel-sided serrated dowel and core and the parallel-sided serrated dowel with an amalgam or composite resin core recorded the highest success rate.
2. The tapered cast dowel and core displayed a higher failure rate than teeth treated without intracoronal reinforcement.
3. The parallel-sided serrated dowel did not have failures caused by tooth fracture, whereas failures of the tapered cast dowel and core required extraction in approximately one third of the fractured teeth.
4. Teeth that had a dowel length equal to or greater than the crown length had a success rate that exceeded 97%.

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